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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

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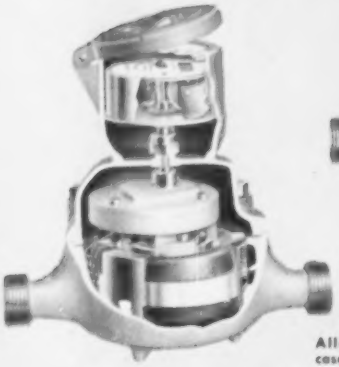

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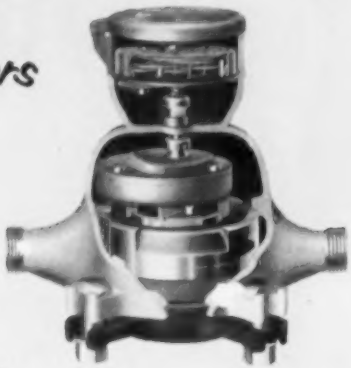

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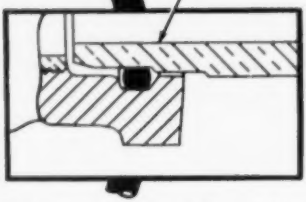

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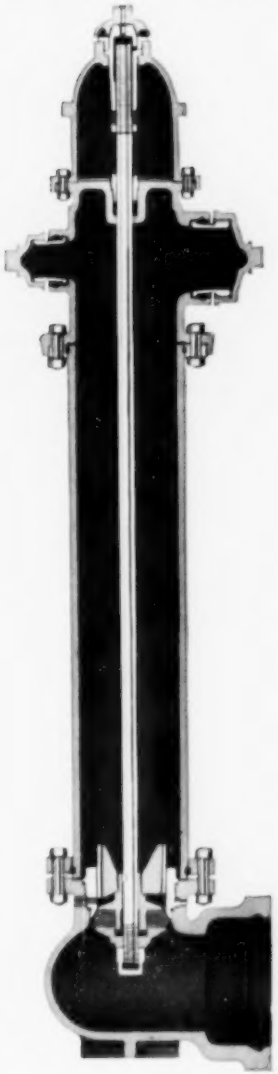

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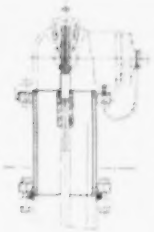

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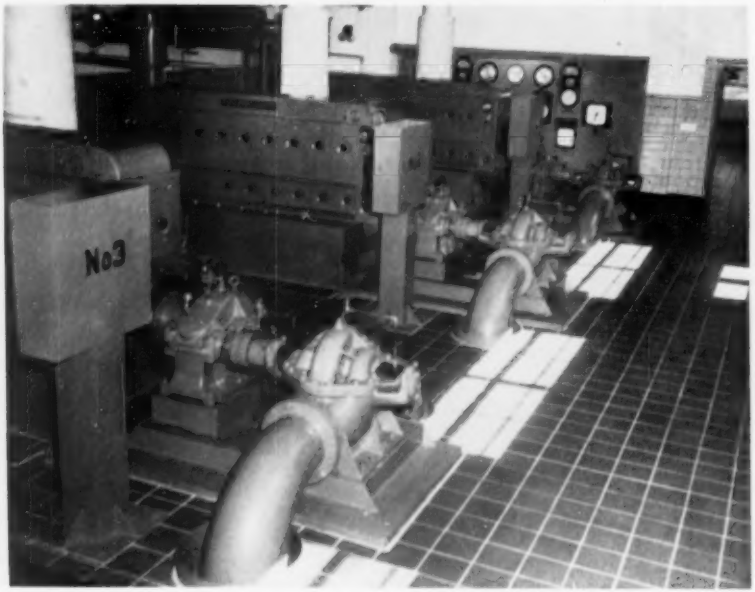

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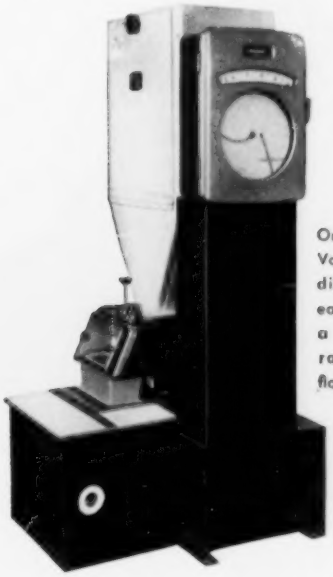

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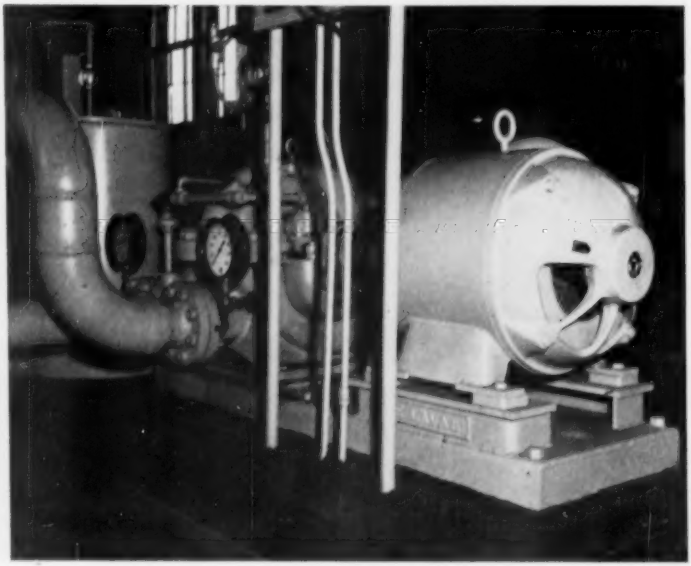

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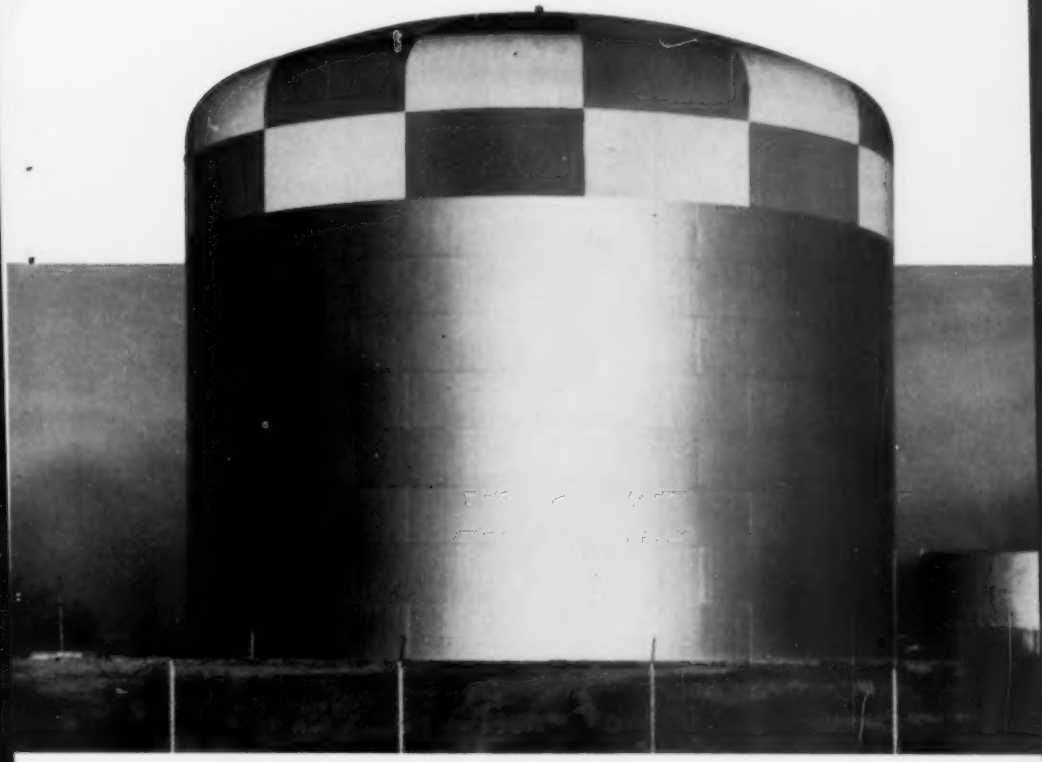

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New England Water Works Association
ORGANIZED 1882

VOL. LXIX JUNE, 1955 NO. 2

This Association, as a body, is not responsible for the statements or opinions of any of its members

INCREASING THE WATER SUPPLY FOR WORCESTER, MASSACHUSETTS

BY C. E. CANNON*

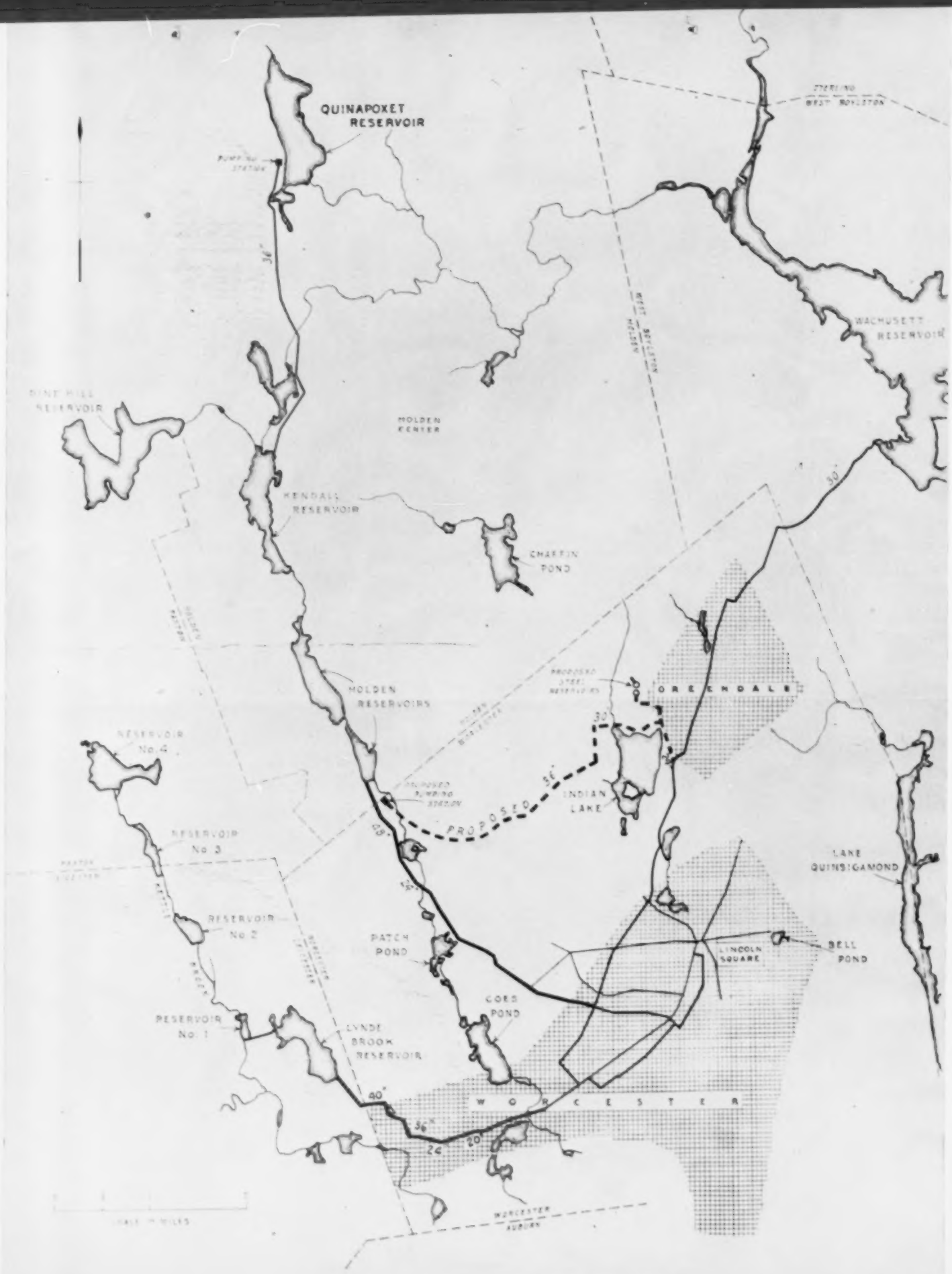
[*Read February 18, 1954.*]

Since 1798, the water-works system of Worcester has been expanded so that the potable water supply has been increased from a minute quantity to 22 mgd. The various reservoirs and some of the large pipes in the present water system are indicated in Fig. 1. The first supply was a spring, piped to only a few houses. The Selectmen were authorized by an enabling act of the State Legislature to utilize this first small supply to extinguish fires. In 1845, the first surface supply was developed, when the waters of Bladder Pond on Belmont Hill were piped into the city. Aesthetics were evidently important in water supply in those days as well as today, since the name of this reservoir was soon changed from Bladder Pond to Bell Pond.

Historical Development. One hundred years ago, M. B. Inches of Boston prepared a very comprehensive report on the development of a water supply for the municipality. With one exception, the sources of supply considered in this report were the ones actually developed during the next 50 years. That exception was Lake Quinsigamond. Use of this source was not carried out, due to the hazards of pollution resulting from the ever-increasing recreational use of the lake and the discharge to it of sewage effluent from the then new State Hospital. Inches concluded that it would not be possible to develop, within the limits of Worcester, a ground-water supply of adequate capacity. This conclusion was substantiated in the decades that followed by the many unsuccessful attempts to drill producing wells.

The Bell Pond supply was expanded somewhat in 1863, but the

*Project Engineer, Metcalf & Eddy, 20 Providence St., Boston 16, Mass.



RESERVOIRS OF THE CITY OF WORCESTER, MASS.

FIG. 1

first important addition to the supply came a year later with the construction of Lynde Brook Reservoir. The opening of the pipeline from the new supply was the occasion of considerable ceremony, during which the pipe burst. Another indication of the growing pains of the water-works profession was the chagrin of the City Engineer to find that the 12-in. pipe at the upper end of a 20-in. line did not adequately supply the larger pipe.

In 1870 and 1871, the dam was raised a total of some 15 ft, but this was followed in 1876 by a major catastrophe in the failure of Lynde Brook Dam. Material in the dam sloughed into an 8-ft arch, which carried the supply pipes through the dam. This sloughing continued until failure occurred. Evidence of impending failure prevailed for about a week before the actual event. During this period a number of emergency measures were taken, but to no avail. However, the advance warning probably helped to prevent any loss of life. Damage to mills, railroads and other property downstream was extremely heavy. The dam was rebuilt as soon as possible, but judging from the report of the Committee on Reconstruction, public interest and criticism was particularly intense.

In the two decades following, four reservoirs on Kettle Brook were developed, from which water was diverted into Lynde Brook Reservoir. In the early 1900's, the Holden Reservoirs No. 1 and No. 2 were developed on Tatnuck Brook, at which time they constituted the low-service supply, and the Kettle Brook and Lynde Brook supply the high-service supply. However, at various periods water has been bled from high service to low, and pumped from low service to high in accordance with the amounts of water available and the respective demands on each supply.

The full development of the Tatnuck Brook watershed was completed by the raising of Holden Reservoir No. 2 and the construction of Kendall and Pine Hill Reservoirs. Although the first of these two new reservoirs is on Tatnuck Brook, the Pine Hill Reservoir is actually in the Wachusett watershed; however, the water from it is diverted into Kendall Reservoir by means of a canal.

Present System. In general, the high-service reservoirs are operated in series, the water flowing through the Kettle Brook Reservoirs and thence into Lynde Brook Reservoir, which acts as the dis-

tributing reservoir for the system. The low-service system operates in a similar manner, with water passing from Pine Hill Reservoir to Kendall Reservoir to Holden Reservoir No. 2, and thence to Holden Reservoir No. 1, the distributing reservoir.

In dry years, additional water has been pumped from Quinapoxet Pond to Kendall Reservoir and then on through the reservoir chain. Quinapoxet Pond occupied a portion of the new reservoir basin described later. In addition, Wachusett water has been pumped directly into the distribution system by a temporary installation, which is dismantled except in emergencies. A 30-in. supply main for the Wachusett supply was laid and the original installation made in the dry year of 1911. Very little use of this source was made until the past decade.

Safe Yields. The dependable yield of the ten reservoirs on Lynde, Kettle and Tatnuck Brooks is difficult to predict accurately, since it depends to a large extent upon the manner in which the reservoir groups are operated. However, it has been estimated that the safe yield of these sources in a series of dry years is 14.5 mgd. This compares with the present consumption of 22 mgd and with an estimated future consumption of 28.8 mgd in the year 2000.

Additional Facilities. With a safe-yield deficiency of more than one-third of present consumption, it can be seen that something more permanent was needed than the emergency pumping facilities at Wachusett Reservoir, which had been bridging the gap. The new Quinapoxet Reservoir solves the problem, as it assures the city of an adequate water supply until about the year 2000.

Development of this supply was suggested prior to 1920, but the first definite action was taken about 1926, when the first of three acts by the State Legislature was passed, empowering the city to build a dam on Quinapoxet River and to purchase the water rights from the Commonwealth for $1,000,000. The purchase of water rights, soon after the legislative acts, was necessary, since the reservoir is on the watershed of the Wachusett Reservoir of the Metropolitan District Commission. About this time, properties of the Walker Ice Co. and others in the reservoir basin were purchased. The Walker Ice Co. properties included Quinapoxet Pond, which, if we may judge from the icehouse foundations, was the scene of sizable

ice-harvesting operations in days gone by. The ice was shipped into Worcester by rail via the Boston, Barre and Gardner Railroad, now a part of the Boston and Maine.

Preceding dry years necessitated, in 1930, the construction of the pumping station and a 36-in. riveted steel force main from Quinapoxet Pond to Kendall Reservoir. The present pumps have a capacity of 22 mgd, about equal to consumption during the past few years. However, the small storage capacity of Quinapoxet Pond severely limited the quantity of water that could be utilized.

The depression following 1930 postponed any further development until marked increases in consumption during World War II once again revived interest in plans for a dam and reservoir on the Quinapoxet. In 1943, the Department of Public Works prepared drawings for the dam. However, the project was temporarily deferred in favor of a project for raising Holden Reservoir No. 1 to the level of Kendall Reservoir. The question involved was whether it would be more economical to provide storage for Quinapoxet River water in a reservoir on the stream before it was pumped, or to provide storage in Holden Reservoir No. 1 after the water had been pumped. By providing the storage in Holden Reservoir No. 1 a reduction in pumpage could have been effected, inasmuch as the additional storage would increase the safe yield of Holden Reservoir No. 1 and its tributary reservoirs, and during wet years some of the runoff in excess of safe yield could be utilized. At that time, 1943, the relation between the additional construction cost for raising Holden Reservoir No. 1 63 ft and the capitalized saving in pumping costs was such that raising Reservoir No. 1 would have been more advantageous than providing storage on the Quinapoxet. Since then, construction costs have risen so much more rapidly than power costs that the Quinapoxet Reservoir project had become the more economical by 1952.

Funds were made available for the design and construction of the Quinapoxet project about the first of 1952. A clearing contract was awarded in March and the general construction contract in July.

The dam, which is about 40 ft high and 1,000 ft long, of earthfill construction, forms a reservoir covering 280 acres with a capacity of 1,200 mil gal.

The 200-ft spillway cut into the southwest abutment is designed

for an overflow rate of 3,200 sec ft, or over 200 sec ft per square mile of watershed. The concrete crest is surmounted by 2-ft hinged flashboards, designed to fail when overtopped 1 ft. The saving effected by the use of flashboards was appreciable, due to the long railroad relocation, the roadbed of which would have had to be raised an additional 2 ft if the spillway crest were set higher and the flashboards omitted.

A model of the spillway was tested out at the Alden Hydraulic Laboratory of Worcester Polytechnic Institute. The original design called for a discharge channel, consisting of a series of steps, to dissipate the energy. The model indicated that the steps would not be as effective as the preliminary design computations had indicated. Professor Hooper and Mr. Neal, of the Institute, then worked out a design on the model for a chute-type channel, with the energy dissipated in a hydraulic jump induced by an 8-ft sill. In order to found the spillway on undisturbed earth and to keep the hydraulic gradient low enough to prevent flooding out at the crest, cuts of 15 to 20 ft were necessary along the channel. However, the material excavated was utilized for railroad embankment or other miscellaneous fills. The channel walls are designed for about 3 ft of freeboard above the water surface at design flood. The model was tested in the comparable flows in excess of the design flood and was found to carry such flows successfully. It was reasonable to accept the design of the spillway without qualms.

It was originally planned to handle the river water in two 36-in. reinforced-concrete cylinder pipes during construction and to use them as blowoffs on completion. However, delivery of this pipe would have been so delayed that the blowoff was redesigned as a 4-ft-square concrete box culvert. The flow through the culvert is controlled by a sluice gate. A 6-in. bypass is also provided, to be used for the release of water if needed to supply minimum requirements in the stream bed below the dam. Water will be taken from the reservoir through a new intake for the existing pumping station on the other side of the reservoir.

The design of the dam section was based on a number of soil tests on test-pit and boring samples in areas where suitable material for the dam appeared likely. Soil tests were first performed on dis-

turbed test-pit samples by Professor Sanger in the W.P.I. Soils Laboratory. Later borings were put down in the areas where suitable material was available, to check the depth to which it extended. The borrow area for impervious material was located on a boulder-strewn hillside. The soil explorations indicated and the actual excavation confirmed the fact that the boulders were on the surface only. Consequently these boulders were not a problem during construction.

An inverted filter, underdraining the downstream portion of the dam, carries the seepage getting through the impervious section of the dam to a tile drain along the downstream toe, which discharges into the brook near the end of the spillway channel.

The cutoff trench in the deepest section of the valley was carried to ledge. Elsewhere, it was carried well into the foundation material, to cut off more of the pervious strata that occur near the surface.

Riprap protects the upstream face of the dam against wave erosion. This riprap was constructed of the large boulders readily available at the site. These boulders were thoroughly chinked, with smaller stone removed from the fill or produced from ledge excavation.

The downstream slope was loamed and grassed. Some sods were used to resist erosion until the grass came up. A berm and gutter on the downstream slope will reduce the concentrations of rain runoff and thus reduce maintenance of this slope.

Construction problems were of a routine nature. Earthwork was handled by power shovels and 3- to 5-cu yd trucks. A 40-ton rubber-tired roller was used to compact the fill. A field laboratory was set up, to control the selection and placing of fill material and also to aid in the control of concrete quality. Construction started in August, 1952, was completed in July, 1953.

Alternate Projects. Consideration was also given to the purchase of water from the Metropolitan District Commission; this procedure would have required construction of a permanent pumping station and intake works at Wachusett Reservoir and another supply main to Lincoln Square for a tie-in with the low-service system. The cost of this construction was estimated at $1,700,000, as compared with $1,200,000 for Quinapoxet Reservoir development. Pumping costs for the Metropolitan District Commission supply would have

been higher also and, in addition, the water used would have had to be purchased from the Metropolitan District Commission.

A dam higher than the one constructed was, at one time, urged by certain interests, to develop more fully the 20-sq mi watershed, but an appreciably higher dam was not feasible in this location. Considerable diking would have been necessary, since much of the land in the vicinity of the reservoir basin is of a rather pervious nature. Extensive and expensive cutoffs would probably have been required under the dikes, to prevent excessive seepage under the higher head. Also, a much greater length of the railroad would have had to be relocated on an entirely new right-of-way and the existing pumping station would have had to be rebuilt at a higher elevation. If some unforeseen circumstance should increase the demand for water above the estimated figure, it would be more prudent to develop another dam site on Quinapoxet Brook at the upstream end of the new reservoir, in preference to providing additional capacity now for the unforeseen circumstance or in preference to raising the dam at that time.

Future Program. The next step in the development of the Worcester water supply will be the construction of a high-service pumping station, pipeline and two standpipes. Plans and specifications have been prepared for this work and construction is expected to go forward in the future. These additional facilities, together with the Quinapoxet Reservoir, will eliminate the need for water-use restrictions that have been in effect during recent summers.

TASTES AND ODORS IN CONNECTICUT WATER SUPPLIES

BY RICHARD S. WOODHULL*

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The problem of tastes and odors in water is one that is likely to affect most water utilities. Today's consumer is displaying increasing insistence not only that his drinking water be safe to drink and free from high color or turbidity, but also that no noticeable taste or odor be present. A common tendency is to place the blame for an unpleasant taste on the chlorine content of the water. How often the consumer expresses the wish that it were not necessary to use so much chlorine! The relation of chlorination to tastes and odors in drinking water will be the primary subject of this paper.

During its history of use for treating drinking water, beginning in the early part of this century, chlorination procedure has developed through several stages. On inception, marginal or normal doses in the range of residuals of 0.1 to 0.2 ppm were employed and accomplished the desired disinfection in many instances to a marked degree.

Tastes associated with this treatment led to the development of the ammonia-chlorine process, whereby it was found that these tastes could be reduced or eliminated. The chloramine residual formed was also found to persist longer, carrying well into the distribution system. It has been learned that residual chlorine in this form, however, does not have the rapid disinfecting power of free chlorine, and therefore a longer contact period is necessary to obtain adequate disinfection. This process is still used on two Connecticut supplies, where filtration plants with attendant storage facilities for treated water make its use feasible. In each of these towns chloramine residuals of 0.2 to 0.3 ppm at the plant are found to carry well through the distribution system.

Another development has been super-chlorination, followed by dechlorination for chlorine-taste control. The initial high chlorine dosage produces improved disinfection over that obtained by a mar-

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ginal dose, and chlorinous taste may be avoided by the dechlorination process, employing sodium bi-sulfite or other reducing agents.

We are now in the era of so-called "break-point chlorination," with an ever-increasing number of utilities taking advantage of the benefits to be found in this treatment. It is by no means to be considered a panacea, but its careful use, in many instances, can solve or greatly lessen taste and odor problems, together with producing vastly improved bacteriological results throughout the distribution system. There appears to have been some lack of understanding of the break-point procedure, which in large measure has probably been due to inadequacies in testing equipment and the fact that we still are not certain of the exact nature of the chemical reactions involved. These chemical reactions are bound to differ with each source of supply, and necessitate a special study of each supply where the use of break-point treatment is contemplated.

In general, it may be said that the "break-point" has been reached in chlorination when free available chlorine is produced and maintained for a period of time. Beyond the break-point, additional dosage of chlorine will result in an increase in free chlorine in direct proportion to the amount of chlorine added. Below the break-point, this is not true and chloramine residuals, rather than free chlorine, are produced. These chloramine residuals are produced by combination of chlorine with organic substances naturally present in the water, and it is in this range that tastes associated with chlorination are normally produced. When sufficient chlorine is added to oxidize the organic matter completely, then the breakpoint is reached. If one goes beyond this point, free chlorine residuals are produced, which have great disinfecting power. However, care is to be taken not to build up the free chlorine too high, else the chlorinous odors associated with free chlorine will be produced. These are most often noted when the tap is opened wide and the volatile chlorine gas escapes to the atmosphere.

In Connecticut there are now 149 chlorination plants on public water supplies, including all public surface-water supplies and many well supplies. It is estimated that 90% of the state's population is served by public water supplies and of this number 98.5% receive chlorinated water.

In the past few years free-residual chlorine treatment has gained wide acceptance in Connecticut. In 1946 there were only 26 supplies in this state where planned break-point chlorination was in use. A tabulation of 252 residual-chlorine tests, made during the regular inspection of chlorination facilities, has indicated the use of free residual chlorine on 71 separate sources of supply out of a total of 106 sources where tests were tabulated. Free available chlorine was presumed present when the flash test was equal to or within 75% of the maximum reading obtained. Whether these residuals are the result of a planned treatment program in all cases, however, appears somewhat questionable. It is also true that 28.2% of these are groundwater supplies, where free chlorine is obtained with only low doses of chlorine. The 51 surface-water supplies utilizing free available chlorine represent 59.3% of all the surface supplies tabulated. It is of interest to note that in only seven of the 252 tests made was interference with the residual-chlorine test found. The maximum interference found was 0.12 ppm and in four of the tests it was present in only trace amounts, as determined by using sodium arsenite.

Observations of tastes and odors are made as a routine procedure when inspecting chlorination facilities. During 1953, a total of 98 observations on 72 separate sources of supply was tabulated. Tastes were noted in 20 of the sources. Chlorinous or slightly chlorinous odors or tastes were observed in 9 sources, of which 8 were carrying free chlorine residuals. These slight chlorinous odors do not seem objectionable in most instances, the odor quickly passing away when a sample is drawn in a glass. Further, most of the observations were made only a short distance beyond the chlorinator, and no chlorine odor was noted in the center of the distribution system. This does point to the fact that care should be taken, in utilizing the break-point procedure, to keep free chlorine residuals within reasonable bounds.

Medicinal tastes were noted in 4 sources of supply. In 3 of these supplies, free chlorine was present, and marginal chlorination was in use on the fourth. The three supplies using the break-point process are troubled at times with tastes and rather high colors prior to chlorination, and the free chlorine has been found to alleviate these conditions to some extent. It is further to be noted that the medici-

nal tastes were not found at the chlorinator plant, but rather at taps farther on in the system, where the free chlorine had decreased and chloramines appeared prevalent, although free available-chlorine residuals have been in use on these supplies for over ten years. The great advantage obtained has been in the improved bacteriological record throughout the distribution system.

Faint swampy tastes were noted in four supplies, one of which was on the break-point process and the remaining three on marginal treatment.

One of the two supplies where ammonia-chlorine treatment is used was observed to have a faint sweetish taste at the filtration plant, but this taste was not observed to carry into the system. Abnormal odors originating at the source of supply are very satisfactorily controlled at this plant through the use of activated carbon.

Other tastes noted were classified as musty, grassy and vegetable, and all occurred in marginally dosed supplies. A breakdown of these observations, together with the prevailing type of treatment, appears in Table 1 and Figure 1 gives a graphical picture of the frequency of occurrence of the various tastes and odors. Abnormal tastes or odors were noted in 27.9% of the observations on break-point supplies and in 23.4% of the marginally dosed supplies. If chlorinous odors are excluded from these figures, the percentage of observations showing unpleasant tastes in supplies treated to break-point drops to

TABLE 1. OBSERVATIONS OF TASTES AND ODORS IN 72 CHLORINATED WATER SUPPLIES IN CONNECTICUT.

Taste or odor	*No. of sources in which observed*	*Prevailing type of treatment*		
		Free available chlorine	*Marginal chlorine*	*Ammonia-chlorine*
Chlorinous	8	8		
Medicinal	4	3	1	
Swampy	4	1	3	
Musty	1		1	
Grassy	1		1	
Vegetable	1		1	
Sweetish	1			1
Total	20	12	7	1

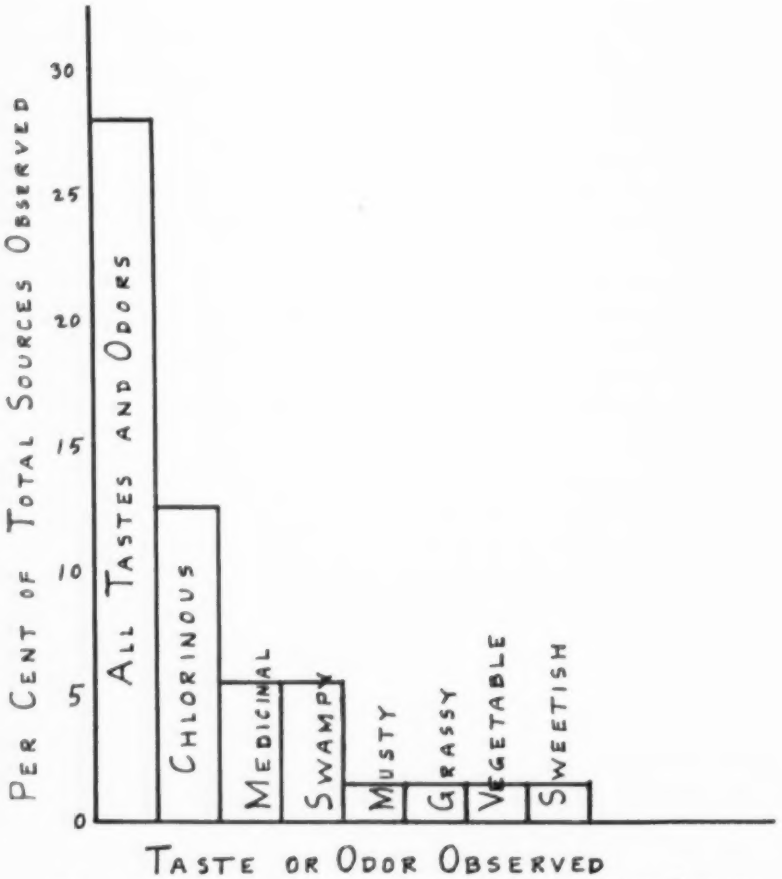

FIG. 1. FREQUENCY OF TASTES AND ODORS IN CHLORINATED WATER SUPPLIES IN CONNECTICUT.

9.3. It should be remembered, in considering these percentages, that many of the supplies now utilizing the break-point process were troubled with tastes when only marginal chlorination was in use, and in all of these cases the taste problem has been improved, if not completely eliminated, after the change to free chlorine.

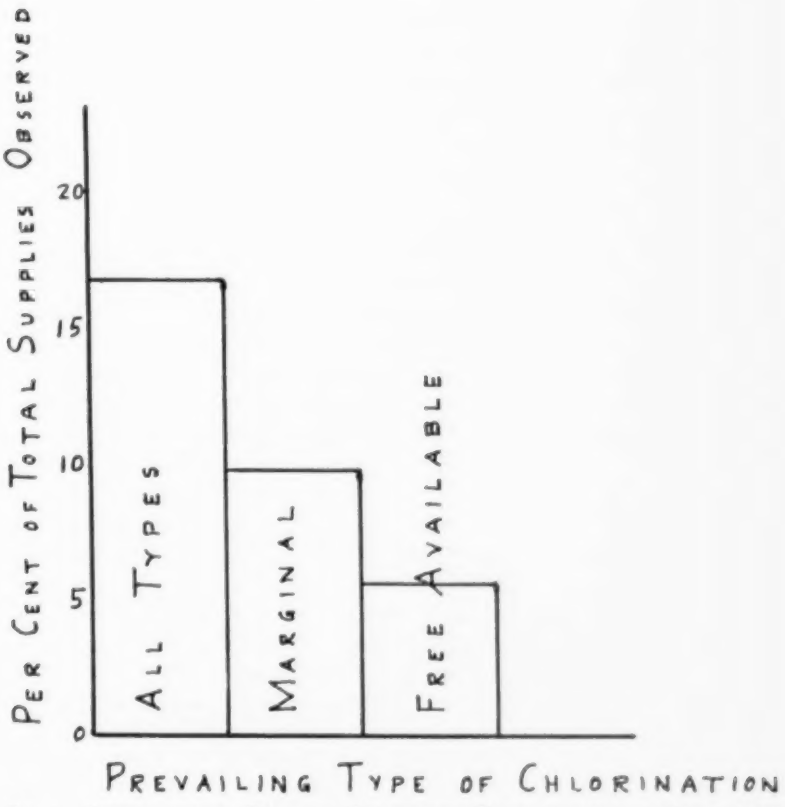

FIG. 2. OBSERVATIONS OF TASTES IN CHLORINATED WATER SUPPLIES IN CONNECTICUT (CHLORINOUS ODORS EXCLUDED).

Looking at these statistics another way, tastes or odors were observed in 16.7% of the sources studied, if the strictly chlorinous odors noted are excluded. Of this number, 9.7% were marginally treated supplies and 5.6% were treated to break-point, as shown in Figure 2.

The figures given have included no observations on so-called "super-chlorination", followed by dechlorination before discharging the water to the distribution system. This method has been employed

to some extent at one filtration plant in Connecticut. Excellent taste and odor control is obtained at this plant, using pre-chlorination, post-chlorination and, after allowing suitable contact time, subsequent dechlorination with sodium bi-sulfite. With this method the advantage of distribution-system disinfection through the carrying of free chlorine residuals is lost, but nevertheless, an excellent bacteriological record has been maintained.

Considerable data have been accumulated by Loiselle, in the treatment of the Bridgeport Hydraulic Co. supply, on the relation of chlorine residuals and tastes to pH values. Free available chlorine is carried in the distribution system and pH values are controlled with lime. Mr. Loiselle found that "iodoform" tastes were experienced when pH values were carried above 8.0 to 8.3, depending somewhat upon the water temperature. By reducing the lime dosage so as to maintain pH values close to 7.6, he has been able to eliminate the "iodoform" tastes. At lower water temperatures, tastes may occur when the pH value rises above 7.9, and when the water is warm pH values may rise close to 8.4 before the "iodoform" taste is noted. Jar tests are made occasionally for control purposes and the program has been carried out satisfactorily for several years.

The one mode of chlorine treatment expressly designed for taste and odor control has thus far had no mention in this report, and that one is chlorine-dioxide treatment. Unfortunately, there has been no opportunity for first-hand experience with the chlorine-dioxide process as yet in Connecticut. From published reports of its use at other locations, it appears that this treatment may well be a useful tool, particularly in those instances where the break-point process may have failed to produce complete removal of objectionable tastes. Chlorine dioxide is reported to have considerable value in elimination of tastes and odors of phenolic origin, and according to Aston (1) its use has been successfully extended to control of tastes and odors resulting from algae, decayed vegetation, weeds, sewage and various types of industrial pollution.

In Connecticut, we are fortunate in having sources of water supply free from discharges of sewage and industrial wastes, our taste problems customarily arising from the presence of algae or decayed organic material. Phenolic tastes may occur at times, usually as a

result of rain washing from freshly surfaced pavements, located near a reservoir. Almquist (2) has noted that when the base of the surfacing material used is asphalt, the condition is less noticeable than when a material with a coal-tar base is used. When the coal-tar product combines in the water with chlorine, a very objectionable medicinal taste is produced. This has been eliminated successfully at filtration plants, but where chlorination is the only treatment available, the only remedy has been elimination at the source.

It may very well be that chlorine-dioxide treatment would prove successful in the elimination of these tastes and at the same time be useful in combating tastes resulting from algae and vegetation to a greater extent than has been achieved through break-point treatment.

Aside from taste and odor control, Aston (1) also reports chlorine dioxide to be an effective bactericidal agent, producing chlorine residuals that persist well into the distribution system. The conventional orthotolidine arsenite test for residual chlorine is said to show one-fifth of the total available chlorine present as chlorine dioxide, but it will not distinguish from any free chlorine that may be present. An oxalic acid—OTA test has been developed, however, whereby it is said this distinction can be successfully made. Aston (1) clearly does not recommend, however, that chlorine dioxide be the sole bactericidal agent employed, but feels rather that it should be used in conjunction with normal chlorination. At filtration plants, the application of chlorine dioxide to the raw water is advocated, followed by additional post-treatment if found necessary.

Erdei (3) has reported that in combating tastes and odors resulting from spring thaws, activated carbon has been found a more successful agent than chlorine dioxide. In treating Connecticut supplies we have found that where facilities for activated-carbon treatment prior to rapid sand filtration are available, very favorable taste and odor control is achieved. It is on the majority of supplies where only chlorination facilities are at present in use, that it appears experimentation with chlorine dioxide might prove it to be an economical tool for control of unpleasant tastes. This might be particularly successful on the three supplies previously noted, where medicinal tastes are still found to occur despite years of free residual-chlorine treatment.

It is by no means desired to leave the impression that the only key to taste and odor lies in treatment. Steps can and should be taken to remove or eliminate the offending substances at the source. A carefully planned, over-all control program will include regular microscopic examination of reservoirs, particularly during the summer months, to determine the type and numbers of plankton present. Based on this information, the appropriate dose of copper sulfate can be applied to destroy the offending organism. In Connecticut, dosages are still commonly based on the rates recommended by Whipple (4) in his classic work, "The Microscopy of Drinking Water". The practice of indiscriminately treating a reservoir with copper sulfate, with no accompanying data to indicate the need and the proper dosage, is not advocated.

It is to be observed, however, that several Connecticut utilities do utilize continuous, light copper treatment by hanging bags of copper-sulfate crystals in streams at inlets to reservoirs during summer months. It is presumed that the chemical will be dispersed throughout the reservoir in sufficient quantity to prevent the start of algae growth. The benefit derived from this procedure seems open to question.

One such Connecticut utility following this procedure has, during the past two seasons, observed a heavy filamentous growth in the reservoir, which has so far defied definite identification. This growth has occurred despite the fact that copper is continuously applied at the inlet of a very small distributing reservoir. Fortunately, no unpleasant taste has apparently been associated with the growth.

Another Connecticut pond supply has served as an example of the possible disastrous effects of copper-sulfate treatment. A heavy plankton growth in the small pond, producing abnormal tastes, was treated, after laboratory identification of the offending organism, with the prescribed copper dose. The result was the establishment of an unbalance of aquatic biological life, causing continued predominance of offending algae. Additional copper treatment seemed only to aggravate the condition. Finally, biological balance was restored and the algae problem solved through the expedient of introducing into the pond organisms determined to be the natural enemies of the offenders. Needless to say, this reservoir has received no fur-

ther copper-sulfate treatment since that experience; also, no further troublesome algae conditions have occurred.

An interesting development concerning the relation of algae to tastes and odors in water has recently been reported by Silvey (5). His investigations in Texas have led him to the conclusion that wherever algae and tastes and odors are found together, the algae are being attacked by actinomycetes, a type of fungus bacteria. The actinomycetes may be growing in association with algae, higher plants, plant remains, or fish and turtle remains. Professor Silvey's experiments have shown marshy, earthy, fishy, geranium, manurial, medicinal, aromatic and chemical odors to be produced. He feels it is possible that tastes and odors in all water supplies may actually be due to the by-products produced by actinomycetes. Such a conclusion would seem to lead to the possibility of taste control through elimination of the actinomycetes, in lieu of concentration on how to destroy their algae hosts.

An illustration of an acute taste problem, associated with algae growth, and the results achieved through copper sulfate and chlorine treatment may be found in an experience of a small Connecticut supply during this past summer. Water is drawn from a small reservoir, having a very limited watershed area with no sources of pollution. Treatment facilities consist of pre-chlorination, slow sand filtration and post-chlorination.

In July, a heavy growth of plankton developed in the reservoir, resulting in a turbid and greenish-appearing water. Filter runs were drastically reduced by the rapid accumulation of organic materials on the beds. Microscopic examination of samples, dipped from the reservoir, showed a heavy concentration of *Aphanizomenon* and pH tests showed a value of 9.0, further indicating the establishment of the algae growth. This growth had developed and remained, despite copper sulfate treatment in April, June and again in July. At the time of the last application the algae were apparently already well established, and experience has indicated that under such circumstances, when pH values have increased to 8.0 or above, copper sulfate is rendered ineffective. Successful algae control necessitates frequent microscopic examination, especially during the known troublesome seasons, so that the proper treatment may be applied before

the plankton become established. It is probably a good rule to treat any algae growth when concentrations exceed 1,000 standard units and, in the case of certain bad offenders such as *Synura*, treatment should begin as soon as they are detected.

With the algae already well established, it was recommended that the pre-chlorine dosage rate be doubled, increasing from 10 lb per mg to 20 lb per mg. This increased the residual chlorine over the filter beds from the previous figure of 0.15 ppm to a residual of 2.0 ppm. The offensive odor on the beds was found to be reduced by this treatment and, following post-chlorination, it was possible to deliver water of satisfactory taste to the distribution system. However, filter runs had been so shortened by the heavy concentration of organic matter that it eventually became expedient to discontinue the use of the reservoir, until such time as the algae condition should become improved.

A second Connecticut supply also experienced a troublesome algae condition last summer, manifested by a dirty, muddy-appearing water in the distribution system. On this supply, chlorination is the only treatment provided. Laboratory examination indicated *Crenothrix* and *Coelosphaerium* to be the causative organisms. *Crenothrix* is known for causing turbidity and scum conditions rather than odor, whereas *Coelosphaerium* is a known odor producer, falling in the sweet, grassy category. Free available chlorine residuals are normally maintained and it appeared that any odor resulting from the *Coelosphaerium* was being eliminated. It was noted that the chlorine demand of the water was higher than usual. Immediate copper-sulfate treatment was applied, with a dosage rate of approximately 3 lb per mg. This dosage seemed to give relief from the muddy-water condition.

In the late fall, trouble was again experienced, this time with complaints of slight medicinal tastes at various points in the system. Microscopic analysis showed no large concentrations of algae in the reservoir, although the water had taken on a somewhat colored appearance. It was noted that, although higher than normal chlorine dosages were being employed, chloramine rather than free-chlorine residuals were being produced. Satisfactory bacteriological results were being obtained and the unpleasant tastes did not persist, so that

no attempt was made to increase the chlorine dosage rate to the point where free chlorine would be established. It seemed that the condition was temporary and probably the result of fairly heavy rain, following a drought period, washing accumulated leaves and other organic material into the reservoir. It was felt that copper-sulfate treatment would be of no value on that occasion and none was applied.

Activated carbon has been used with success, by direct application to open reservoirs, as a treatment for tastes and odors. Bailey and Studley (6) have reported on its use at Rockland, Mass., for combating algae conditions on several occasions with very satisfactory results. They used the activated carbon in conjunction with copper-sulfate treatment, when copper sulfate alone had failed to eliminate the tastes. An activated-carbon dosage of approximately 10 lb per mg is applied, together with a copper-sulfate dosage of 3 lb per mg for each treatment. No filtration of the supply is provided and it is reported that no carbon was observed to enter the distribution system. According to Almquist (2), activated carbon, fed at a dosage rate up to 7 ppm or 58 lb per mg, cannot be detected by the naked eye in a glass of water. In addition to adsorption of tastes and odors, the application of activated carbon to an open reservoir is said to have value in obscuring algae from the penetration of sunlight and thereby reducing further algae growth.

Weeds growing in a reservoir contribute to the organic content and it is therefore desirable that they be removed. The decomposition of the weeds causes an inferior water, the taste of which is likely to be accentuated by chlorination. They can be cut or preferably pulled out by the roots. Almquist (2) has made the observation that riprapping the shore of smaller reservoirs often serves to eliminate weed growth in that area. One Connecticut utility is now engaged in just such a project.

General reservoir quality can also be helped by taking steps to improve run-off from the watershed areas. Several Connecticut utilities have effected improved water quality by cutting channels through swampy areas, to speed the rate of flow and thereby lessen the opportunity for picking up decayed organic material. Planting the watershed with evergreen trees is also a helpful measure, particularly around the reservoir itself, where the evergreens will form a protec-

tive barrier against blowing leaves and debris, and serve to prevent the growth of underbrush.

Aeration has been losing favor in Connecticut as a taste- and odor-control measure. Only a few tastes or odors seem to be much affected by the treatment and other methods of control, which are effective by themselves, are generally found necessary.

Summary

It has been attempted to show that chlorination need not bear the brunt of the blame for the production of tastes and odors in drinking-water supplies. Rather it is felt that this measure, necessary to safeguard the health of the consumer, can also be an effective weapon against the taste and odor problem.

Free available-chlorine residuals have proved of great value in this respect, especially where chlorination is the only treatment provided, and their use has gained wide acceptance in Connecticut. There has been some experience in Connecticut to indicate that tastes associated with free available-chlorine residuals are related to the pH value of the water. One Connecticut utility has found it possible to eliminate these tastes through close control of the pH value maintained in the distribution system.

Ammonia-chlorine treatment may also be used effectively under some conditions, notably at those plants where filtration and storage facilities are available. Chlorine-dioxide treatment has not been tried in Connecticut, but reports from other localities indicate favorable experience. It may be that this treatment would prove of value on some few Connecticut supplies, where break-point treatment has not been entirely successful in eliminating unpleasant tastes.

Aside from chlorination, activated carbon has proved very effective in removing offending tastes at those plants where facilities for its use are available. Direct application of carbon to open reservoirs, where no filtration is provided, may also be useful. Aeration has been to a large extent superseded as a taste- and odor-control measure by other, more effective methods.

Desirable measures to take for elimination of tastes and odors at their *source* include algae control with copper sulfate, weed control and watershed improvement.

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THE BARRINGTON STATION OF BRISTOL COUNTY WATER COMPANY

BY D. F. BIXLER* AND C. E. TROWBRIDGE*

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The Barrington Station of the Bristol County Water Co. in Rhode Island is unusual in that it is unattended and yet provides aeration, filtration, and low- and high-service pumping at two rates. The controls are not extremely complicated and are a combination of standard devices. The station supplies an independent distribution system with about 2,700 consumers and pumps 0.65 mgd on the average, with a maximum pumpage of 1.6 mgd. An 840,000-gal standpipe, floating on the distribution system, has a useful elevated storage of about 375,000 gal, only part of which is normally utilized. This absorbs differences between pumpage and consumption, takes care of short power outages and provides good fire flows. The system was formed several years ago to improve service in the town of Barrington by valving off that part of the company's distribution system and constructing the wells, station and standpipe.

Water is obtained from two 12-inch wells, 80-odd ft deep, in glacial gravel, each equipped with a 1-mgd centrifugal deep-well pump. One well is in the station and the other about 800 ft distant. There are two 1-mgd motor-driven, centrifugal high-service pumps in the station.

The other equipment at the station consists of an aerator, raw-water basin, filters, clear-water basin and chemical-feed equipment.

The 50,000-gal clear-water basin is of reinforced-concrete construction with a cover designed to withstand uplift. On the cover are the chemical room and the raw-water basin. The latter is 8 ft deep, with a capacity of 12,000 gal. On top of the raw-water basin is the aerator, which is in a louvered and screened enclosure above the roof of the station. There are two banks of five steel trays each. The 12 ft x 21 in. x 10 in. trays are partially filled with coke and each

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tray has 610 1-inch holes in the bottom. Water is distributed over the top trays by perforated, 8-inch steel pipes. Water collects on the floor underneath and flows through a hole in this floor (where lime is applied) into the raw-water basin below. The filters are installed in another room of the station, below the level of the raw-water basin. The filters are closed steel cylinders, 9 ft in diameter, with 5-ft straight sides, but function as gravity filters. There are six filters and, at the rated total output of 2 mgd, the rate of filtration is 3.64 gal per sq ft per min, which is satisfactory for iron removal. The filters are equipped with rate controllers and rate-of-flow and loss-of-head gauges. The number of filters was fixed at six, so that one of them could be backwashed at a suitable rate by one of the 1-mgd high-service pumps. Water can also be drawn from the distribution system for backwashing. Palmer surface agitators are provided for use during washing.

There is a venturi meter measuring the station output. There are also lime, chlorine and fluoride feeders.

Operation

The station operates at two rates of pumpage, furnished by one high-service pump alone or by two operating together. One or two well pumps operate automatically as required. Rates of chemical feed are manually set for these two rates of pumpage, with electric controls automatically selecting the proper rate of feed. Aside from these manual settings and manual washing of filters, the station operation is automatic.

When a high-service pump starts up, the chlorine and fluoride feeders are started by means of the electrical controls provided. The lime machine is tied in with the well pumps. The station is started or stopped according to water levels in the standpipe several miles away by means of a telemeter, having switches which control the two high-service pumps.

When the station is shut down, the clear-water-basin level rises in a vent until it equalizes with the level in the raw-water basin. When the high-service pump starts, the draft on the clear-water basin reduces its level. Water automatically flows from the raw-water basin through the filters to the clear-water basin. When the

raw-water-basin level drops to a predetermined point, a float switch therein starts one well pump. If the one high-service pump cannot maintain standpipe levels, the second one is automatically started up by the telemeter. If the one well pump cannot maintain levels in the raw-water basin, a second float switch starts the second well pump. The discharge line from the well pumps is cramped by a float valve in the raw-water basin so as to maintain a suitable level therein. When the standpipe fills up, the telemeter stops the high-service pump. Water continues through the filters at a reduced rate, until the clear-water-basin level rises in the vent to that in the raw-water basin. When the raw-water-basin level rises to a predetermined level, the well pump is shut down.

It will be seen from the foregoing that no attempt is made to maintain levels in the clear-water basin, but that, on the contrary, the level in the raw-water basin is carefully controlled. The clear-water level is lower than the raw-water level by an amount which produces the required flow through the filters. The filter rate controllers function only under abnormal conditions, to prevent a filter from operating at an excessive rate.

This new station was planned for automatic operation. The filters, together with their piping, were carefully placed at elevations below the raw-water basin, so as to avoid any tendencies toward air binding.

The automatic operation has from the start proven satisfactory.

The station is visited at least once a day, to wash filters, check operations, fill chemical hoppers, etc.

From a water-treatment standpoint, the plant also has proven satisfactory. The well water contains approximately 1 ppm of iron in solution, which is reduced to 0.1 ppm. In the aerator, the water rains down between the trays and films out over the coke. Thorough contact with air occurs and the free CO_2, traces of hydrogen sulphide and other volatils are liberated. A small amount of lime is applied to the water flowing from the aerator to the raw-water basin, to neutralize any remaining CO_2 and to provide a trace of phenol alkalinity for corrosion control. Samples are collected regularly from the plant effluent and from the distribution system for bacteriological analysis.

The telemeter in the standpipe, in addition to controlling this

station, also operates a recorder in the company's other station, so that the operator on duty there can be advised of any abnormal condition in the Barrington system. Storage in the standpipe provides service until the difficulty can be corrected. If the trouble promises to be of long duration, valves can be opened and water supplied from the main distribution system of the company.

All the station equipment, including one well, is housed in a brick building. Being located in a high-class residential area, the building was designed along the lines of a colonial residence and presents such a pleasing appearance that several people have inquired if "that house is for sale".

WATER IN PUBLIC HEALTH

BY SAMUEL B. KIRKWOOD, M.D.*

[*Presented March 18, 1954.*]

Introduction

I am happy to be here for three reasons:

1. It is an honor to me personally and as a representative of the Department of Public Health of this Commonwealth to be asked to address your society.
2. Since we are all concerned with the public health, you have a right to know our concept of public health, and more particularly of the rôle we feel water control must play in the over-all program.
3. We do not presume to speak to you on technical matters in which you are the specialists; hence, in presenting our views on your place in the whole program, we are doing so with the hope and expectation that you will advise us—tell us where we are wrong and support us when we are right.

Therefore, I look upon what I am about to say as the opening of a conference and not as a speech on my part.

Concept of Public Health

Let me give you a definition by description:—This is Public Health:

1. Jenner and smallpox.
2. Chlorination of public water supplies.

These two acts constitute probably the greatest steps ever taken in the interests of the public health.

3. Trudeau and tuberculosis and the sanatorium.
4. The school health program and prenatal care.
5. The public health nurse in the home;
   The social worker and housing and home help;

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The nutritionist and the diet;
The health educator.

6. The food and drug and sanitary inspector;
The hospital inspector.
7. The vital statistician, registering births, deaths, marriages and diseases.
8. The physiotherapist and the rehabilitation of the individual handicapped;
The geriatrician, rehabilitating the older person.
9. The practicing doctor and dentist, who sees his curative medicine as one phase of preventive medicine.
10. The community itself in its health-mindedness and provision of facilities.

This is not haphazard arrangement; it is quite purposeful:

Jenner established the principles of the control of mass communicable disease through immunization.

Chlorination established the principles of the control of mass communicable disease through the control of a potentially harmful, environmental necessary of life.

Trudeau established the principle of simultaneous treatment of the individual and protection of the community.

The school health program and the prenatal care program established the principle of general disease prevention through general medical examination of the well person.

The nurse, social worker, nutritionist, health educator established the principle of carrying this general preventive work into the individual home and family.

The food and drug and hospital and sanitary inspector established the principle of prevention in the environmental area.

The vital statistician established the principle of objective analysis and evaluation of health measures.

The physiotherapist and geriatrician established the principle of rehabilitation of the individual as a community responsibility.

The practicing doctor and dentist established the principle of curative medical and dental practice as a basis for broad preventive programs.

The citizen participation established the principle of active community responsibility for health.

We have gone, in short, from the concept of public health as a mass effect of an injurious environment upon the whole population to the concept of public health as the total health of the individuals of the community, and we have come to see that the three people involved in this as responsible for this total health care of the community are:

The Doctor,
The Health Officer,
The Citizen.

All are equally important and necessary; none can function without the other two.

Where Does Water Come Into This Picture?

Obviously, water comes into the picture throughout the entire development of total community health as I have described it.

Let me mention as examples, however, the following:

The production of safe public drinking-water supplies is, as I have said, one of the two outstanding acts of preventive health measures in the world, and needs no further comment.

The service of a safe and adequate water supply is a necessity for the activities of all of the health workers, from the school health doctor to the practicing doctor.

The fluoridation of water supply is the prime example of the function of community water in promoting the individual dental health of the private citizen.

The community service of the water supply goes far beyond the health problems involved and reaches—

Stream pollution, as affecting public recreation;
Bathing;
Industry;
Public safety—fire;

Welfare, through the effect of lowering water tables on agriculture, and irrigation;

Public governmental theory—relative to the transport of water from one area to another (for example, the entire western third of the country) and rainmaking;

Civil defense—radioactive wastes and bacteriological warfare.

What Is the Future Work of Water Control?

In regard to the future work of water control we need your advice. As administrators we have to fit programs and services together, and this often, if not always, means a process of evaluation and selection.

Here we are suggesting the following broad outlines and admit freely our indebtedness to various authorities:

1. It would appear that the whole field of detection and treatment of contamination of the public drinking-water supply should be reviewed, in the light of the startling increase in the last decade of the viral diseases. Present methods of both diagnosis and treatment seem geared to the bacterial contaminants.
2. It would appear that a continuation of the vast industrial expansion that this century has seen will lead to an increased demand for water beyond all previous expectations and forecasts. This should call for study among industrialists, sanitarians and health officers, particularly as to the proper location of plants. The man with the divining rod is still in demand!

   The problem of industrial use applies to the disposal of industrial wastes as well. Each new plant brings its own problems, many of them entirely new.

   Radiological wastes should be considered carefully.
3. It would appear that the problem of stream pollution is not alone one of sanitation, but a very complex one of intercommunity relationships. Unfortunately, our streams and river valleys know no political boundaries. Perhaps your contribution in this field may become recognized as a lead as much to the art of living with one's neighbor as

to the technical side of your specialty. I am profoundly impressed with the necessity of getting on with one's neighbor.

4. It would appear that there is need for a careful study of the principle of the multiple-purpose use of water. With the extensive development of recreational facilities and the recognition of this phase of our lives as an important part not only of the art of living a happy life, but of actually living a healthful life, such use of water becomes highly important.

   The adjunct problems of industrial use, power, and flood control are not always easily reconciled.
5. It would appear that the closely allied problem of over-all conservation of water must be solved. Already our profligate use of this natural resource is having its effect.
6. It would seem that in the present condition of world politics we cannot overlook the possibility of our water supplies' becoming dangerously radioactive or being used as a means of biological warfare.
7. It must be clear that each of these suggestions involves a great amount of basic research. It is worthwhile to urge that this research in some fashion be coördinated and so organized that its results can be translated into proper action.

Conclusion

I have spoken throughout as a health officer and have done so purposively. It is what you should expect of me. But beyond that, I believe it is fundamental to all use of water. No nation is a rich or happy nation without its health.

RECENT IMPROVEMENTS TO THE SHREWSBURY WATER SYSTEM

BY LEW BRIGHAM*

[*Read March 18, 1954.*]

As you probably know, Shrewsbury is situated about five miles east of the city of Worcester and its westerly boundary borders the city of Worcester. The present population is about 13,500. The area of the town is about 30 square miles. At the end of the year 1949, the town had 2,400 services. As you all know, that was the year of the drought. At that time the town had 2 sources of supply. One was the Oak Street supply, with 3 dug wells, each about 32 ft deep, which had a total pumping capacity of 450 gpm. At the South Street Station there was one gravel-packed well, 40 ft deep, from which the pumping rate was about 300 gpm. The low water conditions caused by the drought in the late summer necessitated decreasing the output of the South Street Station to 150 gpm for not over ten hours per day. At the same time, in the Oak Street source of supply, the pumps had to be operated on a basis of pumping 30 minutes and then resting for 30 minutes. This schedule was repeated for 24 hours a day.

This continued for two or three weeks, when the Commissioners issued a drastic order to curtail the use of water and immediately employed the R. E. Chapman Co. of Oakdale, to conduct test-well work in several areas around town, to find an additional water supply. Within a week they had located a good supply and drove an 8-inch test well, into which a temporary pump was installed. In order to get this water, which was between 300 and 400 gpm, into this system, an additional booster pump was necessary. This emergency supply was operated for close to a month. A deep-well pump was installed in place of the suction lift pump, and it operated 24 hours a day for the balance of the year. During this time additional test-well work was carried on and the present Lambert's Pit supply was developed.

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Tests showed that 1 mgd could be obtained from the Lambert's Pit supply and the well was constructed in 1950, with pumping station and deep-well turbine pump over the well. This supply was limited to about 475 gpm, due to a very long 6-inch main in North Quinsigamond Ave, which was used as the discharge main to get this water into the system.

The Commissioners began immediately to have an over-all investigation made of the distribution system, and this was conducted by Whitman & Howard, Engineers of Boston.

The problem was complicated, due to the fact that the town is divided into a high and a low system. One sourch of supply—namely, the South Street Station—is on the high system. The Lambert's and the Oak Street supplies are on the low system. The latter has as its storage facility a 475,000-gal standpipe. At that time the high system had one standpipe of 360,000-gal capacity.

In 1953, an additional standpipe of 500,000-gal capacity was added to the high-service system.

The first step in the improvements recommended was to increase the yield of the Lambert's Pit to its capacity, and this could only be done by laying a large 12-inch main to the Oak Street tank. This was done in 1953.

About half of the water consumed in the town is used in each of the two systems, high-service and low-service. The South Street supply is not adequate to meet the demands of the high-service system, and a booster pump at Oak Street makes up the difference. This Oak Street booster station is an electric motor-driven, 500-gpm centrifugal pump. In order to increase further the supply to the high-service system, the engineers recommended that an additional booster pump be installed on the new 12-inch main. This entails the installation of an electric motor-driven pump with a gasoline-engine auxiliary, which has a capacity of 500 gpm. This new booster pumping station discharges into a 10-inch main, leading directly to the center of town, which is on the high system.

There have been 1,000 new services in the past five years. The consumption in 1950 was 200,417,575 gal and in 1953 a total of 257,137,750 gal was pumped.

On June 9, 1953, Shrewsbury was visited by a tornado. Five

o'clock in the afternoon of that day found the Superintendent sitting in his living-room, looking out the southwest window toward the new school, where he thought the oil tanks were on fire, as a huge black cloud, with white steam all around the edge, was rolling up and moving through the air. To him this twister had the illusion of millions of newspapers, engulfed in this cloud, which, of course, he found later to be roofs of houses, beds and debris of all kinds traveling in this tornado. This was over in about two or three minutes and he still did not realize what it was. He had no calls, because the telephone service had been completely knocked out. He had an engagement with another gentleman in Worcester. They started out down West Main St. and got about one-half mile out of town, but had to turn around because of the trees, wires and poles in the road. They turned back and started out to Worcester by means of Maple Ave., but were confronted with the same conditions. All this time they still did not know what it was all about. They once more tried it by way of Grafton St., but as they approached his residence he was met by his wife, who then told him that a terrible tornado disaster had swept through the town and there was no possible means of communication or travel. Then reports began to come in through the police and other people.

The Water Department employees began to congregate at the Superintendent's house with other information about conditions, one of which was the realization that there was a 30-pound drop in pressure throughout the distribution system. This drop in pressure was believed to be caused by one of the standpipes, which was empty for inspection on June 9. It was believed that this tank had tipped over and ripped out the main, but it turned out that about 200 services had snapped off and all of these small lines were gradually bleeding the system of its storage. About one-half of the storage in both the upper and lower standpipes was lost in the next twelve hours, before the services could all be shut off at the streets. All of the electric power at all of the stations was lost momentarily, but through the fine coöperation of the Municipal Electric Light Department, Lambert's Pit was back in service in about two hours. It should be pointed out at this time that it was fortunate that the source of power for the Lambert's Pit came from the south, as the path of the tornado disrupted all electric power in the northern part of the town.

We were more than fortunate in the fact that none of the waterworks structures—tanks, pumping stations and the like—were demolished or received any substantial damage. The new booster station in the path of the tornado was not completed at that time. One other point of interest is that no hydrants were destroyed, nor any mains broken, by uprooted trees and the like.

The Oak Street booster station was back in service about 2:30 the following morning. Thus the system was back in partial operating condition within less than 24 hours.

The engineers had recommended that auxiliary gasoline engines should be installed, and this certainly proved their necessity. It might have been worse than it was, for we might have been out of electricity for at least 48 hours. South Street was without power for three days.

When the engineers' recommendations are carried out, there will be an additional pumping station at Lambert's Pit, which will make a combined supply from this source of about 1,400 gpm, with auxiliary engines. The large 12-inch main will assist in getting this water into the Oak Street tank, and off of the 12-inch main will be the new booster station, having an electric motor-driven and gasoline engine-driven pump. There will also be a new standpipe, which will add to our storage facilities.

One other point which should be brought out is that the Edgemere Section, which is in the southwest corner of the town, is served by a small main. This year we hope to lay a large main there, in order to supply them with adequate fire protection, and now that we have the additional storage facilities, we have the necessary supply to assure adequate fire protection. We now have about 60 miles of 6-inch main or larger, in addition to about 8 miles of smaller mains.

RECRUITING FOR WATER WORKS

BY JOHN H. MURDOCH, JR.*

[Presented April 15, 1954.]

The work of supplying water to urban communities in America cannot continue unless our ranks are kept up to strength with new recruits. The passage of time alone makes recruitment necessary merely to replace those retiring from service. Growth of population, increase in water use per person and the expansion of our cities and towns require the solving of physical, engineering, chemical, social and economic problems of such magnitude and complexity that constantly increasing numbers in our forces are required. However, numbers alone will not save the developing situation. Our field needs more and ever more well-trained men with the will, the drive, the imagination and the courage to give us progress.

This talk is about how such men can be recruited.

In order to have a frame on which to fashion the talk two texts are suggested:

> "*** Your old men shall dream dreams and your young men shall see visions." Joel 2:28.
>
> "Where there is no vision the people perish." Proverbs 29:18.

Our old water-works men shall dream dreams and that is good—if the dreams have the proper content. It is good for the old men to dream of the days that are gone. They dream of the times less than 100 years ago when public water supplies in America were practically unknown outside of the largest cities and when even they were receiving water, usually, of less than doubtful quality. The old men dream of the days when water-borne dysentery was an expected and accepted condition of life; when typhoid was so widespread and so frequently encountered that those who never contracted it were looked upon as something freakish. The old men dream of filth and flies and

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pollution; of open sewers in civilized communities; of old backyard wells used as sources for drinking water, because the available public supplies were too uncertain in quantity and too obviously dirty to be used. Those backyard wells with the clear, cool water, drawn from surrounding areas long increasing in contamination with sewage, continued in use long after their inherent dangers were recognized, because no better water was available. The old men remember and dream of the unfiltered, unsterilized water, drawn from sewage-polluted rivers and fed into the homes of some of our greatest cities, and they dream of the thousands who died as a result. They dream also of the towns which year by year faced the certainty of depleted supplies, with the attendant necessity of filling bathtubs with turbid water, to last the family until rains would bring some relief.

The old men dream of the civil leaders who brought relief. They dream of the days and years of heartbreaking fight against public apathy, ignorance, prejudice and penny-pinching. The old men dream and remember the long series of trials and errors before sound engineering and financial structures could be built; with fortunes and reputations sacrificed in pursuit of a worthy ideal while lesser men smugly criticized and laughed.

The old men dream of the old days and of the more recent past. They dream of difficulties overcome. Instead of neighborhoods scourged with water-borne disease, they see cities growing and flourishing through the blessing of safe, potable and readily available drinking water. Lives are happier, homes are more secure, population and general well-being advance because—very largely—of the work which these old water-works men did. These old men dream and have reason to be proud in their dreams; proud of their life work and proud of the work of like-minded men who went before them. They have well earned their dreams and their pride.

However, the men who so dream with pride are not usually satisfied with dreams of the past. They dream of the future; of ideals toward which the public water-supply enterprise should be striving. Being old men, they recognize that they will not personally see the ideals attained; indeed they are old enough to realize that if life is to be worth living, there must always be ideals ahead toward which to work. So they dream of the work ahead, hoping and planning to

help, but thinking more of the life of achievement which the young men can take up. These are worthwhile dreams; dreams of the past with pride and with experience gained for sound counsel, and dreams with hope for a better future.

"And your young men shall see visions." For today's purposes, "vision" means a mental image of a bright prospect. "Where there is no vision the people perish."

Water works need men of vision; men who are dissatisfied with present-day conditions; men who can see room for improvement; men who recognize difficulties, but who consider them challenges to be met, if beyond the difficulties they can glimpse a worth-while goal to be reached. We need men of common sense, who can make use of the experience of the past; men of judgment, who can properly weigh values and the relative desirability of goals, compared with costs. We need men who can inspire and lead others toward desirable ends; who can inspire trust and confidence and never betray them. The men we need must also have determination, energy and courage, as otherwise the visions will become mere hopeful dreams. Men of the character and vision we need are uncommon men, but since they are needed, they must be recruited. The type of men we need can be recruited if encouraged to see visions. Visions will not be encouraged if the dreams of the old men lead to prideful self-satisfaction, complacency and mental stagnation. If the old men are so pleased with themselves that they can see no reason to improve service, then young men's visions will be blurred and die. If, on the contrary, the old men's dreams support the young men in their visions, those young men we need will be found and can be recruited.

The young men dream of adequate supplies. Too often they see our towns and cities suffering through periods when normal uses of water must be curtailed or forbidden. Business suffers; lawns, gardens and shrubbery burn out, and homes are threatened with inadequate supplies for sanitation, because the water-works facilities are inadequate to furnish service in dry years. Should the community have a plant capable of meeting peak load conditions during a cycle of dry years, or should it have a plant with a capacity to carry it through years of normal rainfall with the prospect of recurring periods of restrictions on use? If the fully adequate supply be chosen by the

customers, they will be required to pay the carrying charges on a plant which is only needed occasionally. The young man of vision will develop his economic and engineering studies, submit them frankly to the community and let it reach the decision, weighing capital costs against an adequate supply with all the satisfactions which come with such a supply.

Our young men see visions of the solution of some of our source-of-supply problems. They wonder now over the inexplicable apathy of water-works men toward the destruction of our water-supply streams and well fields by pollution. The young men look forward to the day when, through science and law enforcement, the needless contamination of our streams will be halted, and when neighborhoods will not be forced to ever more distant and costly sources of supply. They have visions of better methods of conserving the flood flows of our rivers so that those flows may be used for water supply, instead of causing destruction and a flowing to waste in the oceans. These young men are interested in the modern forester's recent work in cropping watershed timber lands in such a way as to increase the year-round runoff to streams and water-storage reservoirs and, at the same time, bring a good cash revenue to the owner. From their interest in maintaining the capacity of reservoirs, the young men see visions of better land use, better farming, more terracing, more strip cultivation and planting, all to lessen soil erosion and the silting of reservoirs.

We have need for chemists, metallurgists and engineers with vision; men not bound by the rules of thumb, the prejudices and the outmoded formulae of the dead past, but eager to experiment with new approaches to old problems. Great progress has been made in water treatment, purification, and taste and odor control, but ultimate perfection has not been reached. When one set of difficulties is overcome, some scientist invents a new chemical combination, which reaches our water supplies and causes new troubles. Detergents are one of the latest and the answers have not yet been found to phenol. Surely the young men are right, who look forward to improved filter designs and practices, with increasing automatic controls and lessening of capital and operating costs.

Our young men will see visions of improved methods of water

distribution, so that the ever-widening fringes of our cities may be assured of a safe water source. No young water-works man should be indifferent to this and other community problems. Today the capital cost of installing large mains, services and meters in the outlying areas is a very real burden to those who are practically forced to move to such areas. Some day a line of young men will have the ability to devise some better and cheaper methods and material than we now know. We must not be unmindful of the fact that slums and blighted areas are continuing to grow in our cities, taking away customers from our central mains and forcing a dispersion of population into territories which we can reach only at great cost.

Young men will even see the vision of the time when adequate and satisfactory water service will really be offered to our customers and when those customers will recognize its value and will be paying what it is worth. The old men, dreaming of the past, realize that many of our recruiting problems of the present and most of the causes of the inadequacy of the water service which we now give are traceable to our history and to our economic mistakes. Those who first founded our plants had to overcome public indifference to conditions whose dangers they did not understand. Public water supply had to be sold as a competitor with the private wells, cisterns and springs. As a result, the water-works men started a practice, which still continues, of talking about the cheapness of water, comparing the cost of a ton of water delivered with the cost of a ton of top soil, comparing the cost of a day's supply of water with a pack of cigarettes. To make it possible to continue such advertising and competitive selling we are forced to keep down the quality of our service. When our customers ask better service, we say we cannot afford it. We cannot afford the service which the people want and we cannot afford to pay the salaries of the young men who are needed to break the circle. Water service costs money and good water service costs more than merely reasonably satisfactory service, but it is really worth more and young men of vision will find a way to sell that better service for what it is worth.

We need the young men of vision, courage, energy and determination and such men can be found, but they cost money and they must be encouraged when they are secured. Through their visions and their

character they must be given the chance to earn their way—their keep—and they must not be discouraged by lack of opportunity to exercise their talents. Dreams of the past must never be permitted to destroy the visions of a better future. Difficulties must never be magnified. Perhaps there is an easy solution.

Years ago I was in a Pullman drawing-room, going west from New York on the Pennsylvania. My companion was a very great water-works engineer of his day and a good friend. Going through the Jersey Meadows my friend started studying and laughing to himself over a book he had with him, called "Fun with Mathematics." After about an hour he told me—what had been obvious—that this really was fun. To take the kinks out of my tongue I gave him this old problem:

Two men stood facing each other on opposite sides of a mountain. They were exactly 21 miles apart by the road which lay between them. To meet one would walk up a steep slope at three miles per hour while the other came up a gentle slope at four miles per hour. They each walked at their steady speeds until they met. When the one on the steep slope started he knocked a fly off his nose and the fly zoomed up in a wide circle and then flew over the mountain to the other man and flew by his nose. The second man took a swing at the fly, which took a circle one foot more in diameter than he had on the other side of the mountain and started back toward the first man. The fly flew a steady 20 miles per hour without pause, flying back and forth between the men until they met. At each turn, however, he made a circle one foot greater in diameter than the previous one. How far did the fly fly?

My friend studied quietly until we reached North Philadelphia and then said he wished he had his tables of logarithms. At Lancaster he said he could do better by using calculus. I suggested he might be overemphasizing the difficulties of the problem since I, a mere lawyer, had solved it in five minutes. The men were 21 miles apart; one walked 3 miles per hour while the other walked 4—a total of 7 miles per hour; 7 into 21 gives 3, meaning they walked for 3 hours; the fly flew 20 miles per hour for 3 hours. Answer, 60 miles. My friend left the drawing-room and I did not see him again until we reached Pittsburgh. He never forgave me. The moral is—don't

think so much about difficulties—concentrate on essentials and get the answer.

If our old men will dream with pride and hope, but without complacency, and if our young men will see visions of better water service—our future is bright. "Where there is no vision the people perish."

WHAT WATER ANALYSES SHOULD MEAN TO THE PRACTICAL SUPERINTENDENT

BY KENNETH F. KNOWLTON*

[*Read June 17, 1954.*]

This talk is intended to benefit those water-works men who are responsible for water supplies of smaller size which do not have laboratories, and who themselves never had the opportunity to study chemistry.

These men do a wonderful job of maintaining their water systems, in meeting demands for water, accomplishing needed extensions, and somehow getting along on the funds made available to them. They are also responsible for the quality of the water served to the consumer. In many cases I feel that the superintendent is not supplied with sufficient information to play his rôle as effectively in this field as he does in the others. It is my belief that complete results of all analyses of the water supply of a community should be sent to the superintendent by whatever laboratory performs them. Granted, he may not thoroughly understand them, but if he never sees the analyses, he can never be expected to understand them.

Three general types of analyses are made on waters to be used for public consumption. These are:

1. Bacteriological analyses
2. Chemical and physical analyses
3. Microscopical analyses.

The sanitary safety of a water is measured primarily by its bacteria or "bug" content. More specifically, it is measured by its content of those live bacteria found in sewage which originated in the intestines of warm-blooded animals and man.

Basically this is a simple test. It consists merely of placing a sample of water of known amount into a liquid food upon which the bacteria thrive, and allowing growth to take place at the temperature of the human body. Observations for bacterial growth, which is evidenced by fermentation, is made at 24 hours and at 48 hours.

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This basic concept indicates several things to keep in mind relative to bacteriological samples. In the first place, the food does not care whether it nourishes a sewage-type bacterium which was in the flowing stream of water, or one torn loose from the dish cloth used to wipe the sampling tap, or one from the inside of the old peanut-butter jar so often used to collect the sample which is going to the lab. It also indicates that the sample must be received fresh at the laboratory, so that it has the same number of living bacteria as when it was first collected.

Once good samples have been collected and the results reported, what do they mean? Interpretation of the results is the stumbling block to understanding. The United States Public Health Service has adopted standards for purity, while the American Public Health Association and the American Water Works Association have adopted standard methods for analyses.

The purity standard, written in terms which must be studied, is aimed at saying that one intestinal bacterium may be present in 100 milliliters (100 ml or 100 cc) of a water which is safe for drinking. One hundred milliliters are about 3½ fluid ounces. More and more the results of bacteria samples are being expressed in terms of MPN or most probable number of intestinal, or coliform, bacteria per 100 ml. Individual samples may exceed 1 MPN, but the average of all samples in any one month should not exceed this figure.

Another method of reporting results is based upon the actual findings in the test tubes used for making the examination. For presumably good water the test usually consists of placing 10 ml from the sample in each of five fermentation test tubes. This gives a total sample of 50 ml, consisting of 5 identical portions, and results are expressed in terms of the number of portions showing bacterial growth. It will be better to read the Public Health Standards to understand this rating system. It can be described further in discussion following this paper, if any are interested.

Usually the State Health Departments keep posted on the bacteriological quality of a water, and the operating personnel are not questioned too often by the public. However, we quite frequently have people express fears as to the safety of the water when it is roiled up from a fire or similar disturbance. If there has been no main

break or back-siphonage, they can be easily reassured that the safety is not imparied by these upsets, but it is good public relations to collect samples for bacteriological examination at such times. A few samples collected under these conditions can also be very reassuring to the superintendent.

Chemical and physical analyses come closer to the superintendent's telephone. The customer is always making physical analyses as to color, turbidity, sediment, taste and odor. In the laboratory standards can be used to make relative comparisons, but even there the nose and tongue and eye are the prime instruments, althcugh the latter is losing out to the photocell. There is no way that we can tell a customer that the odor or taste of the water at his tap is not objectionable, if he claims it to be such. Tastes and odors are queer things, and it has seemed prudent for me, at least, always to admit to the individual consumer that he is right in these matters. We can point out that others do not object and we can tell what we are doing, if anything, to improve conditions, but the final analysis places his nose against ours. The best we can do is keep on trying for improvement to the limit of our financial and physical means. It is also well to remember that a palatable water at the pumping station does not insure that the taste will be the same at the consumer's tap.

Color is not apt to be a cause of complaint if it is constant, but any change in color can cause complaints. We had one consumer who questioned the quality of the water, and the foreman answering the complaint drew a bottle of water from the tap, looked at it and said it seemed OK to him. With the lady still dissatisfied, I was called to make a more thorough check. The tap water looked all right, but she said it was yellow in the toilet bowl. Some quick and private conclusions were drawn until the bathroom was investigated. It contained the whitest, cleanest water closet I have ever seen and this closet was located beneath a north window. This lady had a better apparatus to determine water color than I had in the laboratory and she had readily been able to see the gradual change from 8 ppm color to about 15 ppm, which had taken place in our supply over a period of a month or two. When she was informed as to the cause and learned of our extensive, routine sampling program, she was apparently satisfied.

Of the strictly chemical tests, the ones most frequently of concern to the consumer seem to be hardness and total solids. In this day of steam irons and automatic washers, the instruction booklets packed with these appliances usually tell the purchasers to call the local water department to determine one or the other of these factors.

Right here is a convenient place to discuss units. Most modern water analyses on public supplies express the results in terms of parts per million by weight (ppm), but in some cases, especially dealing with hard water, the units are in grains per gallon. Instruction booklets enclosed with appliances vary in their terminology and since 1 grain per gallon is equivalent to 17.1 parts per million, it is important that the consumer obtain the correct figure.

Hardness is the measure of the soap-consuming power of the water and is important in washing procedures where a detergent is used. A steam iron evaporates the water and, consequently, the item of interest is usually the total solids left upon evaporation. This is also of interest in dish washers, where the water dries on the dishes. Household softeners remove hardness by changing the chemical forms in the water, removing one material and substituting another for it, and actually increase the total mineral solids in the water. They could conceivably cause more severe spotting of dishes than the original hard water.

It would seem advisable to have a card, lettered with both the hardness and total-solids content in both grains per gallon and parts per million, at the telephone table in the office, so that questions from consumers may be answered promptly.

Next in line for rearing its ugly head before the superintendent is probably iron. This very useful material has no place in a good water supply, except to keep the water in its place in the form of pipes and tanks. The iron content of water can be very readily determined and should be checked frequently enough to detect any tendency towards change. Iron may be present in the raw water from wells in a clear, dissolved form, known as ferrous iron, which turns to red iron rust upon contact with air, or the iron may be due to corrosion of the distribution system. Tests for iron should be performed on the distribution system, as well as at the pumps, in order to get a clear picture of the quality of the water.

Manganese may also be present in a water and may not show up until years after a supply is developed. This material causes brown and black stains.

Water-quality standards allow a total of 0.3 ppm of combined iron and manganese. This is purely an aesthetic standard, since these materials have no effect upon the health.

Many other chemical determinations are made upon water for various purposes and any which are reported should be checked against past analyses, to see whether changes are taking place.

Of these other determinations alkalinity and pH are almost always shown in any chemical analysis, because they are simple to perform and give considerable information to the analyst. They are also good indicators of changing conditions.

Total alkalinity is a measure of the total quantity of alkaline materials in the water and is determined by neutralizing these materials with an acid of known strength. High alkalinity and high hardness tend to go together, and waters containing appreciable alkalinity or hardness are usually less corrosive to piping materials.

Hydrogen-ion concentration (pH) is a measure of the strength of the alkaline or acid materials in the water, rather than a measure of the total quantity. Its values range from 1 through 14 with the neutral point at 7. Above pH 7 the water is alkaline and below it is acid. It is perfectly possible to have water with a pH of less than 7, which is acid, and still have alkalinity present. This is because all of the alkaline materials do not complete their chemical change until enough acid is added to lower the pH to about 4.7. Therefore, between pH 4.7 and 7.0 the water has an acid reaction, but still contains alkaline material. Since variations of many kinds affect the pH, it is a simple and sensitive indicator of change. It indicates a condition rather than a material.

The two gases, carbon dioxide and dissolved oxygen, when present in moderate amounts, tend to increase corrosion. Accurate tests for each of these must be performed, at least partially, in the field.

The various ammonia and nitrogen tests measure organic matter and are often advance indicators of pollution on the watershed area.

The common orthotolidine test for residual chlorine should be familiar to all who have chlorinators and will not be discussed here.

However, I should point out that the commonly reported analytical figure for chloride is a different substance—namely, common salt. It is often a useful sanitary test to indicate sewage or waste contamination of the water source.

Those superintendents practicing fluoridation are probably all familiar with at least one test for this material.

A knowledge of the general characteristics of the water, in addition to being a quality-control factor, can also frequently aid in the identification of leakage. Several years ago we experienced a situation where leakage of water appeared in a basement. In the area there were water mains of two different communities, as well as old and unknown drains. The area was near tidewater and contained considerable rock fill. Analysis of the water showed that it could not come from one of the public mains, because it did not have sufficient color. The salt content was low and the season was dry, so that it was doubted that it was ground water from the area. This information was sufficient to cause the start of a search for leakage in the water main of the other community and a cracked bell was subsequently found. Again, very recently, a similar situation arose at another home in the same area. This time the salt content of the water was quite high, and at present both communities involved are applying fluoride to their water. The seepage in question contained no fluoride and the water departments were absolved this time.

Recently, on our own supply, consumption seemed to be too great for the conditions thought to exist and the water-department foreman spent considerable time in cruising about all the remote spots where a leak might go unobserved. The only suspicious spot located was a highway culvert, where there was seepage from the top and sides. Samples of the seepage showed the same fluoride content as the water in the distribution system, thereby definitely determining the source as the water main. The use of the fluoride determination should permit the identification of fluoridated water in a flowing stream, if the fluoridated water consists of about 10% or more of the entire flow.

Residual chlorine can sometimes be used to trace leaks and has been used at least twice on our system.

The third general type of analysis is that for plankton, or algae,

growths and is known as microscopical examination. All who are responsible for surface supplies are probably familiar with the troubles which can come from the growth of these microscopic plants and animals. They are also probably familiar with the method of control by copper sulphate.

These organisms are observed and counted with a low-power microscope, and most of them can actually be seen with the sharp naked eye. May I suggest a simple test? Take a sample in a clear, one-quart or larger bottle, hold it up to a good even light and practice looking into the water in the bottle. The larger forms of water fleas can be easily seen swimming about, but the smaller, troublesome forms of algae can be seen as a course turbidity. They cannot, of course, be identified this way, but some practice will enable the superintendent to catch the start of growths in time to arrange for samples to be examined or to treat his supply with copper sulphate.

Actual microscopical counting is not difficult and, I feel, should actually be performed more frequently directly by the personnel in charge of surface supplies. I also feel that the method could be adapted to very inexpensive microscopes and other equipment, with a great loss in accuracy, but nevertheless with sufficient accuracy for routine control purposes.

My reason for recommending on-the-spot facilities is that these growths can often build up in a week and cause serious taste before routine monthly analyses could catch them. Observation of turbidity in the water, followed by a simple identification of the predominant organism, should make it possible to nip many algae "blooms" in the bud.

I have tried to give this talk with a minimum of technical vocabulary, in an effort to get more practical men to appreciate the factors concerned with water quality. Our public and our industry are becoming increasingly aware of water quality as well as quantity, and we should be able to answer their questions intelligently and, wherever possible, help to solve their water problems.

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MAINTENANCE HAS A FOURTH DIMENSION

BY LEWIS T. JESTER, JR.*

[Read October 5, 1954.]

The fourth dimension in maintenance is becoming increasingly important in the light of the tremendous expansion predicted for the electrical industry in the next 10 years. This fourth dimension can play a large part in reducing and simplifying electrical maintenance in new water works, and in old ones which must be expanded and modernized to meet the predicted demands that will be imposed in the next 10 years.

Electrical maintenance is usually considered a necessary evil after the equipment has been installed and is in operation. It consists broadly of three dimensions—equipment listing, maintenance planning and maintenance execution. The fourth and very important dimension is system selection and equipment application during the planning stages. Proper consideration, in this fourth dimension, can materially reduce maintenance problems encountered during actual operation, as we shall see.

The electrical portion of a water-works plant can be separated into power-distribution equipment and power-utilization equipment. Let us see how distribution-system planning can affect maintenance.

Adequate interrupting capacity in circuit breakers and adequate capacity for growth in both plant load and in the power system supplying the pumping station should be provided. A circuit breaker or fuse, barely capable of handling short-circuit currents today, may not be adequate 5 years from now, because of the increase in utility generating capacity which will occur to supply the tremendous additional amounts of electrical power predicted to be needed in the next 10 years. A breaker called upon to interrupt more than its rating may cause an explosion and the damage to the breaker, as well as to surrounding equipment, can mean plenty of maintenance and repair.

The system should be planned so that increased loads at low

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voltage may be supplied from additional transformer capacity, without increasing the interrupting capacity on the bus beyond safe limits. A load-center secondary selective system with normally open tie breakers will permit this.

System neutral grounding can be a great help in reducing and simplifying maintenance. In ungrounded systems the equipment winding would normally float with the neutral at ground potential. However, if a line-to-ground fault occurs, two phases are immediately subjected to 173% of normal voltage to ground. If the ground is intermittent the insulation may be subjected to 5 to 10 times normal voltage to ground—enough to damage motor insulation and cause additional maintenance.

If the system neutral is grounded, a fault is immediately located and cleared, with resultant safety to personnel and with minimum equipment maintenance.

Solid system grounding on the high-voltage side of a line exposed to lightning permits the use of lightning arresters rated for line-to-neutral voltage. These arresters have a lower spark-over voltage than those which must be used on ungrounded systems and therefore permit less lightning impulse voltage to reach the equipment. Also, station-type arresters have lower spark-over values than distribution or pellet-type arresters. They should be used wherever possible, to hold switchgear stresses below their rated impulse level and to limit the distribution transformer stresses to 50% of the standard impulse-level rating for best life. This 50% takes into account repeated stresses on insulation and oil, as well as possible depreciating effects of overloads, moisture, etc.

Arresters properly applied ahead of any fuses which may be used can also prevent a great deal of fuse blowing and replacement by maintenance men, by diverting lightning discharge currents from fuses. It is obvious that well-planned lightning protection, coordinated with distribution-equipment impulse levels, can save a lot of time and expense and insure better continuity of service.

Liquid-filled transformers have approximately double the impulse strength of dry types and are quieter, and the non-flammable liquid prevents the entry of moisture and dirt.

When selecting and applying cable, consideration should be given

to its ability to withstand fault currents which may be imposed, as well as its continuous current-carrying ability. Often a cable selected to carry the load current will be too small to stand heating imposed by short circuits and therefore the insulation may be weakened and eventually cause a shutdown, requiring emergency maintenance to restore service.

Reasonable peak temperatures for most insulations on cables are in the vicinity of 150°C.; at 175°C. disintegration of insulation may occur, with attendant smoke and combustible vapors.

Protective relay and circuit-breaker operating times also must be considered to select the minimum cable size. Overcurrent and short-circuit protection in the system should be coordinated, so that the protective device closest to the fault will operate first to clear the line. This prevents breakers farther back up the line from opening and possibly killing the entire power supply. Coordination studies can easily be made for a new or an old installation, to insure proper selective operation.

We have talked about distribution, let us look at the utilization side of the picture. Control may be split into two groups, high and low voltage. Both have some common characteristics which can help to minimize maintenance.

Metal-enclosed grounded equipment retards entry of foreign material and protects the equipment from physical damage. Since moisture and fumes are sometimes a problem, control should be installed in an uncontaminated area where conditions require it. Back-connected units provide more space for wiring and equipment and are generally easier to maintain. Grouped control, with units factory wired and assembled, also simplifies maintenance, since the maintenance man is provided with a coordinated wiring diagram with control interlocking shown. The majority of connections are made within the enclosure, and this simplifies and reduces the number of cable connections, conduits, cables and maintenance which separately mounted units would require.

Motor starters should provide overload protection, as well as adequate short-circuit protection. These two should be coordinated in a single unit, so that the fuse or circuit breaker will allow the overload to protect the motor up to its design limit, then take over and

protect the control, overload unit and motor from currents too great for them to handle. This well-coordinated protection, which is almost impossible to secure from separate combinations of fuses and controllers, is readily available in standard combined equipments. Coordination means that only the desired protective element will operate for any particular trouble. Instead of being faced with the problem of replacing or resetting two elements, the maintenance man need reset only one.

Where a large number of repetitive operations are to be made—say starting or stopping a motor—contactors are the best choice for minimum maintenance. Where large motors require infrequent starting, electrically operated circuit breakers alone may be used. Air circuit breakers, 50-250 mva, 4,160 v to 13.8 Kv, are suitable for 2,500-15,000 non-fault duty operation before inspection and maintenance is required.

When motors are to be selected, careful consideration should be given to several factors, in order to secure the most trouble-free design. If a motor is specified with too high a voltage rating for a given horsepower, there is a high ratio of insulation to copper, which results in a soft, less rigid coil. This type of coil is hard to wedge and difficult to brace, and the coil connections are more vulnerable to vibration. Large motors at reasonably high voltage give a much better ratio of insulation to copper and are therefore subject to less maintenance.

Low-voltage motors also have a greater insulation margin than high-voltage motors as far as high potential tests are concerned, but, on the other hand, motors with too low a voltage have coils which are too large and stiff to handle easily and are expensive and impractical. High-speed motors are more difficult to brace than low-speed motors, since the coils must span a greater distance.

Ambient conditions, such as corrosive fumes and moisture, indicate that enclosed motors should be selected for minimum maintenance. Space heaters may also be necessary.

Since the motors in water works are subject to considerable moisture in the air and may be shut down for extended periods, consideration should be given to protection against moisture, to avoid additional maintenance caused by damp insulation. Three methods are

available—heating the insulation, treating the winding with extra varnish dips and bakes, and totally enclosing the motor. Of the three, heating is the most effective. Extra dips or totally enclosed construction will delay the entrance of moisture, but if the down time is long enough, moisture will eventually penetrate the insulation. If a motor is to be idle for short periods of time—say 10 to 20 days or so—extra insulation or totally enclosed construction will be sufficient, but never as good as insulation heating. Insulation may be heated by space heaters or by applying single-phase power to the windings. The latter is limited to 60-hp sizes and below, because of expense of control equipment, space heaters being more economical above 60 hp and easier to maintain in all sizes.

Motors connected to high-voltage lines, exposed to lightning, should be protected by arresters and surge capacitors, connected as closely as possible to the machine terminals. Absence of protection could mean winding failure and emergency maintenance. The arresters limit the impulse voltage and the capacitors reduce the effect of steep lightning wave front, which tends to concentrate high voltage in the first turns of a coil and cause insulation breakdown.

Now that the system and equipment have been selected to make maintenance as simple and inexpensive as possible, let us hear from Mr. Ruling and Mr. Hansen on what to do with the equipment after it is in operation. When you are planning a new plant or studying an old one to improve it, remember to say "Fore" just as you do on the golf course—before you swing. Then you can plan your steps so the ball won't hit you or someone else on the head.

MAINTENANCE OF POWER-DISTRIBUTION EQUIPMENT

BY ALBERT H. RULING, JR.*

[*Read October 5, 1954.*]

In general, maintenance of power-distribution equipment—that is, switchgear, breakers, transformers and their associated control devices—is a little different from that of other equipment. The frequency of inspection depends upon local conditions, but, as a rule, a complete inspection should be made at least once a year. Casual inspections can be made oftener, while equipment is being cleaned. The extent of the inspection and maintenance will be governed by the size, importance of continuity of service, location on the system, and operating conditions, such as ambient temperature, unusually dirty atmosphere, heavy fogs, and so on.

It goes without saying that some types of equipment will require more attention than others. Transformers and switchboards require relatively little attention, compared with other electrical equipment. For transformers, checking of the oil, cleaning of insulators and checking of protective devices will usually suffice. Switchboards require little more than cleaning and checking of the tightness of joints in the bus work. More attention will be required by circuit breakers and relays, for in addition to cleaning they require periodic testing, lubrication, and inspection for worn and eroded parts. Strange as it seems, the less this type of equipment is used, the more important becomes the testing. Breakers which must remain in either open or closed position for long periods should be operated occasionally several times in succession. This will help to keep all parts in working order. The same goes for relays.

The maintenance of power-distribution equipment is usually neglected, because there are not many moving parts; that is, breakers and relays usually stay in one position for long periods. Then too, there is the problem of the equipment's being energized most of the time and it is inconvenient to "kill" the equipment to work on it, unless it is absolutely necessary.

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Proper maintenance is a scheduled maintenance program. There are many names for a scheduled maintenance. A couple of the newest I have run into lately are "productive" and "protective" maintenance, but no matter what it is called, a properly scheduled maintenance program is the key to greater plant efficiency, regardless of the nature of the plant. Naturally you people are interested in waterworks operation, and to secure trouble-free efficient operation, you should have a maintenance program and keep the program on schedule.

Perhaps I should define just what I mean by a scheduled maintenance program. It is not just doing a certain thing to a certain piece of equipment at a certain time. No, it is much more than that. In addition to the usual lubrication and cleaning, there are periodic tests to be made and records to keep. The program would also include the keeping of adequate spare parts, necessary test equipment, and the training of personnel. The importance of tests and records cannot be over-emphasized, for by analyzing the results of the tests, it is possible to determine the extent of maintenance required. By examining the records, it is possible to determine the necessary frequency of the various operations of maintenance.

Properly scheduled maintenance can eliminate causes of shutdown due to equipment failure, because your periodic inspections keep you informed of the condition of your equipment at all times. By making the proper tests, you are assured that your safety equipment will function when an emergency arises. Records of your maintenance will tell you when you should replace equipment that has passed its usefulness. The equipment that requires frequent costly repairs should be replaced. Without keeping a record of cost of any individual piece of equipment, it is sometimes hard to detect those which are "nickel and diming" into an inefficient operation.

I could tell you of many instances of failures due to lack of maintenance: bus failures due to loose joints, which would have been detected had the equipment been cleaned occasionally; breaker failures, not due to lack of maintenance, but rather due to lack of proper maintenance and lack of proper equipment to test closing speeds. I could tell you of whole plants shut down because no one took the trouble to read the instruction books, covering the equipment on which they were working.

Then, on the other hand, there are those examples of good maintenance. Just a month ago, one of our customers detected water in one of his transformers during a periodic sampling of the oil. The transformer was dried out and a costly failure averted.

Proper maintenance also means the carrying on hand of adequate spares and supplies. For example, another one of our customers lost a 3,000-hp motor, due to a surface air-cooler failure, which sprayed the inside of the motor with salt water, but, because this customer had on hand a set of spare coils for this motor, it was repaired and returned to service in about one-half the time which would have normally been required.

The solution of most maintenance problems is to set up a program. The scope of the program will be dictated by the installation, financial position, personnel and the necessity of continuity of the service involved. In your particular case, it is essential that you maintain your service; therefore, you require a strong program.

Just as in everything else, there are many different maintenance plans. There are progressive plans, where a little bit is done at frequent periodic inspections and so, at the end of the year, all of the equipment has had a complete and thorough going over. And there is a plan whereby a little work is done monthly; the monthly plus a little more quarterly; the monthly and the quarterly plus a little more semi-annually, and then the big job annually.

Regardless of the type of plan used, its scope will be determined by local conditions and the size of the installation. The people who are operating the installation should be the ones to set up the program, for they are the people who know the conditions best and who must execute the program. Manufacturers, such as we, can recommend and advise, but operating people in the end must determine their own program. As I have mentioned before, records must be kept. The exact nature and extent of these records are entirely a matter of personal choice.

The results of a good maintenance program are deceiving. When the plan is working at its best, there are not many emergency breakdowns and everyone is leisurely doing his bit. This is when a short-sighted management does not realize why things are going so smoothly and usually begins to wonder if all this maintenance work and

expense is absolutely necessary. This is also the time when the program is hardest to keep sold, because it is possible after a period of good maintenance to stop all such work and no ill will result for some time. Sooner or later the blow will come. Good maintenance is like insurance. As long as it is in force, you will never seem to need it.

MAINTENANCE OF MOTORS AND CONTROL

BY WALTER HANSEN*

[*Read October 5, 1954.*]

Be sure to check new installations of motors, controls and replacements soon after putting them into service. Some maladjustment may be discovered that might cause real trouble if the scheduled inspection date is far ahead.

Dampness from excessive temperature and humidity will, in time, deteriorate the insulation of motor windings, and grounds or short circuits will occur. Particular care must be given to frequent inspection, maintenance and repair of motors operating under such adverse conditions.

Insulated Windings

Tests for General Condition

The megohms (million ohms) of resistance between a motor winding and ground is a good indicator of insulation condition. Comparison with several previous readings will give an indication of improvement or deterioration. Reading should be taken with the machine at normal working temperature. Readings, to have comparison value, should be taken under the same conditions.

Two methods of obtaining resistance readings are commonly used:

1. A megohmmeter is a self-contained instrument which gives a direct reading of insulation resistance.
2. The voltmeter method requires a voltmeter having a resistance of about 100 ohms per volt. A 500-volt instrument is preferred. Disconnect all leads of the motor from the line.

A.I.E.E. Standards establish the following "Normal Insulation Resistance Value":

220-volt motor—0.2 megohm
440-volt motor—0.4 megohm
550-volt motor—0.5 megohm

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Cleaning Windings

Grease and oil can be removed by the conservative use of a suitable solvent. After this cleaning, dirt can be blown out. Excessive applications of solvent will soak into inaccessible places, where it may soften and harm insulation.

Bearings—Mechanical Considerations

Air-Gap Measurements

Measurement of air gap is made primarily as part of maintenance procedure to indicate sleeve-bearing wear. Measurements made at the lowest part and on the sides will usually indicate any eccentricity. Quiet operation, adequate torque, desired power factor and efficiency, as well as motor temperature, depend upon a reasonably concentric air gap.

To measure air gap, preferably use a tapered air-gap gage. Air gaps of larger machines, such as synchronous motors and generators of low-speed design, and in d.c. machines are substantially more than for smaller machines, particularly induction motors. However, the air gaps should be within 10%, as measured under main poles. On large, open machines, where the air gap is accessible, revolving air-gap measurements are made by taking the measurement at one reference point on the rotor and then revolving the rotor, to measure four points on the stator.

Stationary air-gap measurements are made by measuring four points on the rotor from one point on the stator.

Lubrication of Bearings

Old oil should be drained from the housing at least every year. Remove the drain plug from the bottom of the frame, where available, and flush out any foreign materials which may have accumulated. On motors not equipped with drain plugs, the end-shield bolts should be removed, the end shield rotated and the bearing cleaned, before reassembling the end shield and adding new oil.

If motors are equipped with waste-packed bearings, re-oil every 1,000 hours of operation.

DO NOT OIL BEARINGS WHILE THE MOTOR IS RUN-

NING. This causes the oil to get into the windings and "slop-over" the floor, causing a fire hazard as well as an accident hazard.

Ball Bearings

Ball bearings should be regreased at intervals commensurate with their size and service. The following is a recommendation.

RECOMMENDED REGREASING PERIODS

	Horsepower		
Service	¼-7½	10-40	50-150
Standard	5 yr.	3 yr.	1 yr.
Severe	3 yr.	1 yr.	6 mo.

MAINTENANCE OF CONTROL

The major cause of relay and contactor failures is dirt and moisture. When relays operate frequently they will, if properly designed, tend to clean themselves of most kinds of dirt at every operation.

If a relay operates fairly frequently and is given reasonable protection from such types of dirt and moisture as may be present where it is mounted, it may be expected to complete a long and useful life without requiring any attention. However, where relay operations are infrequent, or where moisture and dirt are present, frequent cleaning is necessary where a relay is mounted in a housing. Not only the relay itself, but the entire interior of the housing, should be cleaned.

Many contactors, up to 100-ampere capacity, as well as small relays, utilize fine-silver contacts, which oxidize more slowly than copper contacts. When silver oxide is formed on the contact, the oxide is self-reducing. Therefore, it is not necessary nor recommended that fine-silver contacts be filed to remove the oxide. It does not take much filing to destroy the contact's usefulness completely.

If sulphur gas is present in the atmosphere in any quantity, a sulphide may form on the silver. If the contact pressures are light and the voltage low, this condition may prevent the current from flowing when the contacts close. The sulphide is darker in color than the oxide and should be removed by cleaning if it causes trouble.

Copper contacts oxidize rapidly at elevated temperatures and slowly at room temperatures. The copper oxide which is formed has a very high resistance. A few strokes with a file will remove the oxide and reduce the resistance to low value again. It is usually unnecessary to file copper contacts if the device is operated fairly often. The slight abrasion produced by the ordinary closing operation is sufficient to keep the oxide cleaned off. However, if corrosive gases are present or if the contact controls a highly inductive circuit (such as a d.c. machine field), the oxidation may progress more rapidly and it is usually better to substitute a special type of contact, for which information may be obtained from the manufacturer.

A fairly common erroneous impression is that contacts which have been roughened by service should be kept smoothed, so that they will carry the load. A roughened contact will carry current just as well as a smooth contact. Of course, if a large projection should appear on a contact, because of unusual arcing, it should be removed. However, a contact that has been roughened by ordinary arcing need not be serviced. If a copper contact becomes overheated, this condition indicates that oxide has developed and the oxide should be removed.

Do not lubricate the contact face, because the burning of the lubricant on circuit interruption increases the heating of the contact and shortens the life of the contact.

As the contact wears, pressure is maintained by the wiping spring, which presses the movable contact against the stationary contact when the contact is closed. Check this spring at intervals, since contact heating may draw the temper of the spring and reduce the pressure of the contacts. The correct spring pressure is usually indicated on the instruction sheet accompanying the controller.

Modern motors and their associated control equipment are the brawn and brains of your plants. You will be well repaid for a few hours spent on proper protective maintenance of this vital portion of your plant.

RADIATION EXPERIENCES IN MASSACHUSETTS WATER SUPPLIES

BY RALPH M. SOULE*

[Read October 6, 1954.]

The development of the atomic bomb with its release of radiant energy has resulted in considerable concern regarding the effect of such radioactivity on water supplies. Although this source of radioactivity is new to us, it is not new that we are constantly subjected to similar radiation from the sun and naturally radioactive substances in the soil around us.

In the Annual Report of the Department of Public Health in the year 1916, the Division of Water and Sewage Laboratories reported on "Studies Made Relative to the Radioactivity of Natural Waters". This study was brought about because of the assertion that certain waters were radioactive to an extent that they had a therapeutic value. It was felt also, at that time, that the investigation was worthwhile because of the possibility that water containing radioactive substances might have an influence upon the growth of algae in ponds and reservoirs. It was interesting to the author to learn that, as early as 1916, radioactivity was known to be of three characteristic forms of radiation, which were referred to as alpha, beta and gamma rays. It was recognized also, at that time, that radioactive substances had a life or decay time, and the activity was referred to as microcuries per liter.

Radiation was first discovered in the year 1896, when a photographic plate was placed near certain ores of uranium. The plate was affected in the same manner as if it had been exposed to light. It was found also that even if the film were covered with a thin paper, it was affected, the indication being that the rays could pass through such paper. Pierre and Marie Curie succeeded in isolating in small quantities two new substances from uranium ore. These were named radium and polonium.

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Let us consider that all matter is made up of atoms which, in turn, are made up of nuclei with surrounding fields of electrons, all having negative charges. The nucleus consists of neutrons and protons. The protons all have positive charges. Every chemical element has a specific number of protons in its nucleus. However, some forms of the various elements have more neutrons than others, and when the ratio of protons to neutrons becomes unbalanced the nucleus of the atom releases energy. All radioactive materials emit one or more of the following forms of radiation: Alpha, beta or gamma particles. Alpha particles have a speed of about one-tenth the speed of light or about 18,600 miles per second. These rays are non-penetrating and are dangerous only when inhaled or ingested. Beta particles have a speed nearly 95% of the speed of light and are dangerous if contained in water or food which may be ingested. Beta rays in sufficient concentration can cause permanent injury or even death, if a major portion of the body is exposed to such radiation. Gamma rays are electro-magnetic rays of very high frequency and, like radio waves, cannot be seen or felt by human beings. Gamma rays are extremely dangerous and may penetrate the skin, causing serious tissue damage even if not inhaled or ingested (1).

Consequently, it was felt desirable for the Department of Public Health to examine, for radioactivity, samples of water from various sources subsequent to the test explosion of atomic bombs. In doing this, it would be possible to establish background data so that any large increase in radio-activity could be detected. Because of the numerous tests, however, it is probable that these background data had been affected by atomic explosions which had already carried radioactive materials to this area and had been deposited in our natural waters through precipitation. Nevertheless, samples examined in 1951 from 100 surface waters and 100 drinking waters showed almost negligible radiation.

Radioactive material is constantly disintegrating. The rate of disintegration is referred to as the "half-life". This half-life varies from a period of seconds to millions of years and it is obvious, therefore, that a radioactive material which has a half-life of a very short period of time, such as minutes or hours, is of no particular interest to the sanitary engineer since its danger decreases to inconsequential

values in a very short period of time. The rate of disintegration is measured by curies. The curie is the number of atoms in one gram of Radium 226 which disintegrates per second (1). Since both the total number of atoms and the decay constant of a gram of radium are known—37 billion atoms are disintegrating each second—a curie may be defined as that quantity of radioactive material which disintegrates at the rate of 37 billion disintegrations per second.

It is most inconvenient to deal with such astronomical figures and, therefore, three smaller units of radiation are commonly used. These are the millicurie, which is one-thousandth of a curie, the microcurie, which is one millionth of a curie, and a micro-microcurie, which is one millionth of a microcurie. The author does not pretend to be an expert in the field of nuclear physics and is, therefore, not going to attempt to explain the significance of the units of disintegration, or the units of exposure to radiation. Those who are interested in this matter and wish to pursue the subject further are referred to the bibliography which will be found at the end of this paper.

Laboratory Methods

The method used by the Lawrence Experiment Station in measuring the radioactivity of water is in general as follows: 100 or 200 milliliter samples are evaporated in porcelain dishes and the residue is transferred to steel cup planchets 25 millimeters, or about one inch, in diameter and 4 millimeters deep. These planchets resemble ordinary bottle caps. The concentrated samples are then evaporated to dryness by infra-red heat. The radioactivity in the dried sample is measured with a Geiger Muller counter and the count is transferred to a machine which records the number of minutes required for a count of 512 disintegrations. The machine (Figure 1) may be set to record the number of minutes required for a count of 2, 4, 8, 16, 32, 64, 128, etc., up to 4,096 disintegrations. The scale varies geometrically. If too low a setting is selected and an unusually "hot" sample is examined, the machine may be thrown out of adjustment. The 512 setting, therefore, appears to be the most appropriate for this work. Samples and empty background cups are placed alternately on the automatic sample changer.

One microcurie of radium isotope is equivalent to 2.22 disintegra

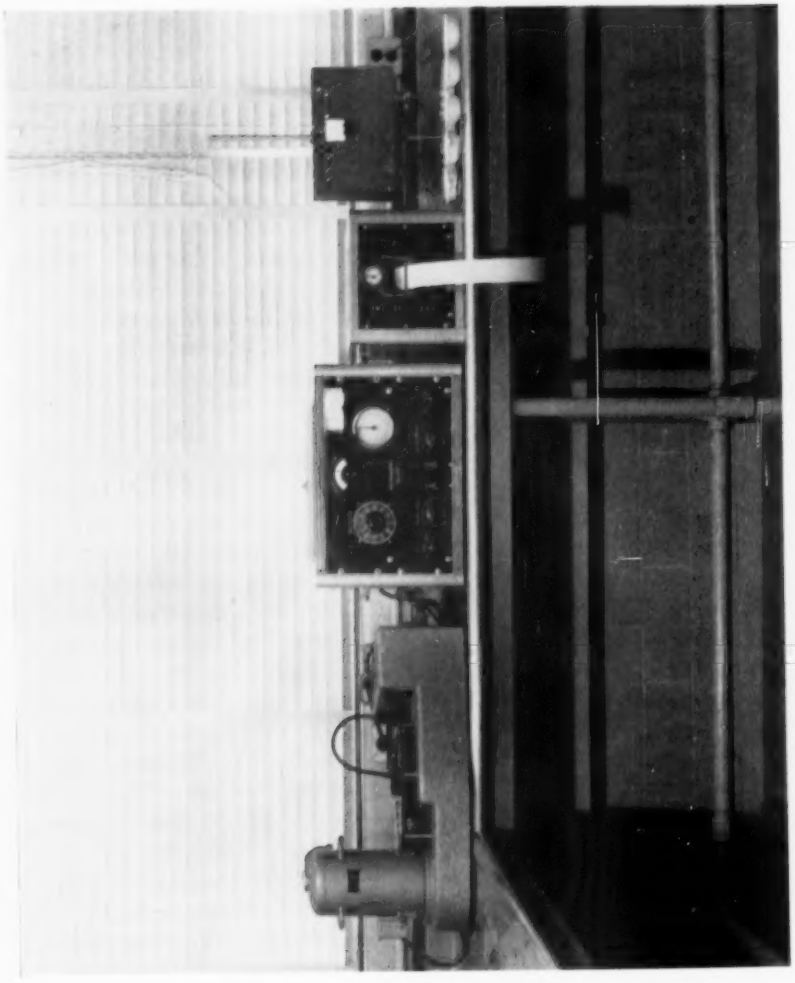

FIG. 1. APPARATUS USED AT LAWRENCE EXPERIMENT STATION FOR MEASURING THE RADIOACTIVITY OF WATER SAMPLES.

tions per minute. By the number of counts per minute, therefore, the observer could theoretically convert to microcuries. However, present-day counting machines do not measure all of the disintegrations which occur, and it is necessary to make an assumption as to the efficiency of the machine to convert the readings to microcuries. The basic data and background studies being made by the Massachusetts Department of Public Health are just as useful, when recorded as counts per minute per liter, since all the data are comparable. The maximum permissible radioactivity in drinking water in constant use has been set (3) at 100 micro-microcuries per liter. This amount of radioactivity in a sample of rain water examined on the apparatus of the Lawrence Experiment Station would be exceeded during times when the precipitation is affected by nuclear fission products. Such concentrations, however, would continue only briefly.

Relation of Radioactive Rainfall to Air-Mass Movements

The normal air-mass movements in the northern hemisphere are from west to east. Therefore, when an atomic explosion occurs which carries radioactive material thousands of feet into the air, that material normally is carried in an easterly direction, and when climatological conditions are right, it will be carried to the earth with precipitation. The time and direction of travel of the air mass movements vary considerably, due to the development of weather patterns. For example, an air mass over Nevada may pass over New England from two to five days later. On the other hand, it may pass to the south or north of New England.

The capriciousness and unpredictability of our New England weather, with which we are all so familiar, may therefore be a blessing to us. If, as sometimes happens, an air mass becomes stagnated west of New England, it may release all or most of its radioactive materials through precipitation before it reaches us. It may also be pushed out into the Atlantic, passing north or south of New England. At any rate, the release of radiant energy in the atmosphere over the western part of the United States does not necessarily mean that the radioactivity of rainfall over New England will be increased.

In the samples examined from Quabbin Reservoir during the past three years, lower count-rates have been observed than in samples

of water from other sources. This is due, undoubtedly, to the long period of storage and the greater opportunity for solids to settle out of this unusually large, quiescent body of water (*2*). This fact bears out the important point that radioactive material in water is reduced by sedimentation and storage, as well as by other ordinary methods of water purification, as will be shown later. If we should be subjected to frequent rainfall unusually high in radioactivity, more research would be required to develop treatment for more effective removal of radioactive substances.

Observations of Radioactive Rainfall

Following the April 6, 1953, Nevada detonation, Massachusetts had a very large radioactive fall-out which showed up during the rainstorm of April 7 and 8. During this portion of the studies, fourteen rainfalls occurred and the count-rates of the fall-out, which can be considered as an estimate of the concentration of the radioactivity in the atmosphere, are shown in Table 1. The count rate of the rainwater was about 99,000 counts per minute per liter on April 8. Rain received five days later gave a count-rate of 3,310 which was about 3% of the initial high count. After one week it had dropped

TABLE 1.—CONCENTRATION OF RADIOACTIVITY IN RAIN WATER AND IN THE MERRIMACK RIVER.

	C.p.m./l rain*	*Relative values*	*C.p.m./l Merrimack R.*	*Relative values*
April 8	98,980	100	913	100
April 13	3,310	3.31	56	6.13
April 14	341	0.34	53	5.80
April 17	370	0.37	14	1.53
April 21	330	0.33	7.7	0.84
April 27	411	0.41	7.5	0.82
April 28	235	0.24	28	3.07
May 1	213	0.22	49	5.37
May 4	110	0.11	19	2.08
May 6	56	0.06	6.5	0.71
May 8	166	0.17	6.8	0.74
May 18	111	0.11	6.5	0.71
May 25	115	0.12	26	2.85
June 29	105	0.11	24	2.63

* C.p.m./l. = counts per minute per liter.

to about 0.4%; in about a month it was only about 0.1 of 1% of the original strength. This concentration persisted until the end of the period of study, June 29.

The decay rate of the "hot" rainfall of April 8 is shown on Table 2. In five days the count-rate had dropped to nearly 24% and in about a month to 1% of the original activity. The count-plates on Table 2 were obtained by counting the original cup-planchets at various times.

TABLE 2.—DECAY RATE OF RAINFALL OF APRIL 8, 1953.

	*C.p.m./l**	*Relative values*
April 8	98,980	100
April 13	24,170	24.4
April 16	12,540	12.7
April 21	4,880	4.93
May 1	2,110	2.13
May 8	1,600	1.62
May 15	1,220	1.23
May 22	912	.92
June 12	666	.67

*C.p.m./l = counts per minute per liter.

River Measurements. During this period, the Merrimack River, which had about 1/100 the concentration of radioactivity on April 8, rapidly fell to about 6% in five days and persisted at nearly 2% for the period of study. The above results are shown, also, on Table 1.

Lawrence Filter Plant. Samples were taken daily during the test period at the following sampling points:

Intake—Merrimack River at intake to city filters.

Settled—Coagulated and settled water.

R.S.F.—Effluent of rapid sand filter.

Reservoir—Reservoir from tap as leaving to distribution system from 7 to 8 feet below surface.

Shop—Tap in center of city on the low service system.

The data for the count-rates were divided into three groups, namely April 8, April 13 to 17, and April 21 to June 30. During the period immediately following the Nevada blast of April 6 about 41% of the activity passed through the filter plant, and after a period of

a month when the radioactivity of the raw intake water had dropped considerably about 52% passed through the plant. As can be seen by observation of Table 3, practically all of the radioactivity removed was in the coagulation and settling basins. It is of interest to see that the reservoir had a relatively high count immediately following the detonation, which probably represents the fall-out directly into the open reservoir.

TABLE 3.—CONCENTRATION OF RADIOACTIVITY PASSING THROUGH LAWRENCE FILTER PLANT.

	April 8	*April 13-17*	*April 21-June 30*
No. of Samples	6	5	37
	Average counts per minute per liter		
Intake	410	50	13
Settled	226	42	5.7
R.S.F.	169	43	6.6
Reservoir	552	35	5.7
W. W. Shop	168	30	6.8

Reduction in Radioactivity by Various Treatment Methods

Table 4 shows the reduction in radiation in rain water when treated by various methods and tested at the Lawrence Experiment Station:

TABLE 4.—REDUCTION IN RADIATION BY VARIOUS TREATMENT METHODS.

	Counts per minute per liter	*Per cent reduction*	*Counts per minute per liter*	*Per cent reduction*
Rain water	69.4	——	221.0	——
Filtered through filter paper	37.6	45.8	165.0	25.4
Membrane filter	47.6	31.4	167.9	24.0
Coagulation with lime or alum	47.2	31.8	67.1	69.6
Filtered through 18″ of sand	13.9	79.9	22.8	89.6

It will be noted that substantial reductions in radioactivity were attained by filtration through sand. Filtration through the membrane filter resulted in much smaller reduction, and since the porosity of the membrane filter is much less than a sand filter it must be assumed that the sand removed the radioactive material by adsorption, possibly by electrolytic means.

The radioactive properties of water are contained in some mineral or solid substances in the water and if the mineral or solid substance is removed by sedimentation, coagulation, or filtration the radioactive material is removed also. The disposal of sludge from the treatment plant, if unusually high in radioactivity, may present somewhat of a problem but with the exercise of due caution such materials may be disposed of by burying in the ground, or other similar means, so that no danger will result even when radioactive materials of long half-lives are encountered.

Radioactive material in water supplies is not necessarily derived from atomic explosion. Such materials are used in industrial research centers and in the treatment of certain diseases in hospitals. The careless disposal of radioactive waste material can lead to serious pollution of natural waters and potentially harmful results. Recognizing these dangers, the Atomic Energy Commission controls the distribution of radioactive isotopes and has instituted measures of control to reduce the dangers of radioactive pollution (3).

The Massachusetts Department of Public Health has always guarded against pollution of water supply sources and will continue to be active in this matter whether the pollution is chemical, biological, or radioactive.

Acknowledgments

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WATER PURIFICATION IN CAMBRIDGE, MASSACHUSETTS

BY DAVID H. TURCOTTE*

[Read October 6, 1954.]

The purpose of this paper is not to present any new revolutionary format for water purification, but rather to present a summation of the progress made in the development of the present water-purification works of the city of Cambridge and to present in proper sequence the part which each integral part of this plant performs in the purification of water.

Source of Water Supply

In 1856 the city of Cambridge drew its first public water supply from Fresh Pond (a natural lake situated in the western part of the city). As the city grew in size, additional sources of supply were required and, to meet this need, the Fresh Pond supply was supplemented with water brought in a conduit from a storage reservoir, constructed on Stony Brook, a tributary of the Charles River, in Waltham and Weston.

In 1897 a larger storage reservoir was completed on Hobbs Brook in Waltham, Lincoln and Lexington, to augment further the city's supply.

Health Problems

The pumping of untreated surface water into the city supply mains presented a health risk to the consumer. In 1922 the Water Board made an intensive study of the various methods of water purification. Through the tireless efforts of these men, a filtration works was constructed on the shores of Fresh Pond and put into operation on the 25th of April, 1923.

Capacity of Plant

The plant was constructed to yield 14 mil gal of purified water per day. Incorporated in the features of this plant were sedimenta-

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tion basin, ten rapid sand filters, wash-water tank, back-water wash tank, aerator unit and a clear-well reservoir.

Plant Addition

In 1932 the original plant was expanded when six additional filters were added to the plant. This increased the maximum output of the plant from its original 14 mgd to 22.4 mgd.

Problems Arising from Increased Output

The increase in the filtration rate produced serious breakdowns in efficient plant operation. With the increased velocity of flow of treated water through the sedimentation basin, detention time was decreased and the necessary time for floc formation and settling was lost. The results due to the loss of detention time in the sedimentation basin were a sedimentation effluent high in color and one containing much unsettled floc. This water, applied on the filters, caused short filter runs and necessitated constant filter washes, with consequent loss of filtration output. In other words, the load of purification was carried by the sand filters. To overcome the defect in plant output, the plant was remodeled and expanded in 1950-1952, at which time mixing and flocculating chambers were added and the original, tank-type sedimentation basins converted into three tray-type compartments.

Functions of Integral Parts of the Purification Works

Water drawn either from Fresh Pond or from Stony Brook Reservoir is treated with alum solution just prior to its flow into the mechanical mixing chambers.

In the mixing chambers the solution of alum mixes rapidly with the water, due to the action of fast-moving mixing paddles. The mixing of the alum solution with the raw water brings about a chemical reaction between the natural alkalinity factors in the raw water and the alum, producing a new chemical compound which has amazing properties. This new compound (aluminum hydroxide) forms a *colloidal sol*, which cannot be seen by the naked eye. These colloidal particles have a positive charge of electricity which causes the particles to repel each other, thus preventing coagulation. The organic coloring matter in surface water is also colloidal, but negatively

charged, which also prevents its coalescence. The basic reason for agitation in this basin is to bring the two oppositely charged colloids together and cause them to precipitate. Oppositely charged colloidal particles have an affinity for one another and thus bring about their neutralization and the coagulation of the colloids. In the flocculating basins the neutralized aluminum hydroxide begins to become visible at the influent end of the basin and the floc becomes much larger at the effluent end of the basin.

Properties of the Floc

The aluminum-hydroxide floc has tremendous adsorption power, due to its extremely large surface area. This floc has the ability to adsorb the organic coloring matter which was thrown out of colloidal solution previously in the mixing chambers. Bacteria germs, microscopic organisms and turbidity are also adsorbed by the floc.

Effective Sedimentation

The sedimentation basin at the Cambridge plant allows a detention period of approximately 1.63 hours when processing 22 mgd of water. This time is quite sufficient, because the floc which was formed in the flocculating chamber gets larger and heavier, due to its adsorption of impurities, and settles to the bottom of the sedimentation basin. With the removal of the floc in the basin, the sand filters give about 140% longer filter runs and a saving of about 50% in wash water.

Sand Filtration

The clarified sedimentation-basin effluent is filtered through 27 in. of filter sand (effective size, 0.5 mm and uniformity coefficient, 1.5), to strain out unsettled floc, coloring matter, turbidity and microorganisms. The formation of a light film of organic matter on the grains of sand assists in the filtration of the impurities. With the water flowing through the sand at the rate of 2 gal per sq ft per min, more and more impurities collect on and in the voids between the sand grains, producing a loss in output so great that effective filtration is lost. Before this point is reached, the filters are taken out of service and the impurities washed from the sand.

Removal of Impurities

The filter sand is cleansed by the upward flow of water through the sand at a rate of 15 gal per sq ft per min. At this rate, the water expands the sand and sets the impurities in motion, and they are subsequently removed with the wash water. This operation requires about five minutes and the use of 40,000 gal of water. Factors which have been responsible for short filtration runs have been traced to microorganisms, mechanical failures and insufficient floc removal in the sedimentation basins.

Purpose of Aeration

The effluent of the filters collects in a flume, from which it discharges into an aerator, consisting of riffle plates studding a sloping surface. This facilitates good mixing of water and air, and causes the dissipation of volatile odors and most of the dissolved carbon-dioxide gas.

Chlorination

A continuous application of chlorine to the aerator effluent destroys bacterial contamination and maintains effective sterilization of the filter effluent.

Reasons for Corrective Treatment

The addition of alum to the water entering the mixing basin causes a chemical reaction between the alkalinity in the water and the alum. One of the products formed is carbon dioxide. The liberation of this compound in the water produces a lowering in pH. In order to overcome the corrosiveness of this water, hydrated lime is added to the purification-works effluent, to neutralize this CO_2 and to provide an excess of 5.0 ppm of natural carbonates.

Under these conditions, a protective film of natural carbonate is maintained on the supply mains, providing protection against corrosion and the ultimate development of red water.

Plant Operation

The successful operation of the Cambridge purification plant has been due to laboratory control tests and to the assistance and cooperation of the personnel required to operate this plant.

Tables

Tables of analyses and plant operation are submitted as a part of this paper, to give the reader a more intimate knowledge of the efficiency of the Cambridge purification works.

The tables of operation include the records of the first two years and each succeeding five-year period. The years 1952 and 1953 were compiled to show the effectiveness of the plant since being remodeled in 1952-1953.

TABLE 1—SUMMARY OF OPERATION AND CHEMICAL TREATMENT
(Compiled from yearly averages of daily results)

Year	Millions of gallons filtered	Length of filter runs (hr)	Wash water (%)	Chemicals (lb per mil gal) Alum	Lime	Chlorine
*1924	13.04	9.8	4.5	189	98	2.4
1925	13.02	11.1	5.7	183	86	2.9
*1930	13.38	11.6	4.8	164	82	2.9
1935	13.27	15.2	3.7	159	84	2.2
1940	13.83	15.4	4.3	165	79	1.9
1945	16.39	16.7	5.1	189	99	4.6
1950	17.20	15.3	4.5	222	96	7.4
†1952	16.50	29.4	2.5	167	78	5.4
†1953	17.03	36.2	2.0	157	70	4.5

*Soda ash used instead of lime.
†New flocculating and sedimentation basin in operation.

TABLE 2—SUMMARY OF BACTERIOLOGICAL ANALYSES
(Compiled from yearly averages of daily results)

	Bacteria per cc on agar at 37° C.				Presumptive B coli per 100 cc			
Year	Raw	Coag.	Filtered	Effluent	Raw	Coag.	Filtered	Effluent
1924	130	45	6	0	16	0.3	0	0
1925	100	37	4	1	8.0	0.2	0	0
1930	187	101	27	2	22.6	8.1	0.1	0
1935	61	35	4	2	24.0	8	0.2	0
1940	128	40	120	1	26.8	1.8	0.2	0
1945					43.0	3.8	1.2	0.3
1950	95	68	35	2.5	92.4	28.2	1.5	0
1952	92	45	44	2	67.2	9.9	6.2	0
1953	232	82	46	1.3	78.4	9.3	3.0	0

TABLE 3—SUMMARY OF PHYSICAL AND CHEMICAL ANALYSES
(Compiled from yearly averages of daily results)

Year	Color			Alkalinity			Carbon dioxide					
	Raw	Treated	Effluent	Raw	Treated	Effluent	Raw	Treated	Effluent	Raw-water pH	Effluent pH	Temp. of effluent
1924	37	27	2	17.0	7.0	16.0	3.0	13.5	4.0			53
1925	38	29	3	16.0	5.5	17.0	3.0	14.5	3.5			53
1930	27	27	3	19.0	10.0	22.0	3.0	10.0	0	7.0	8.2	55
1935	27	23	3	19.0	9.5	22.5	3.0	12.0	0	7.0	8.7	53
1940	29	26	3	21.0	10.5	22.5	3.0	12.5	0	7.0	8.8	53
1945	34	31	4	23.0	11.7	28.5			0	6.80	8.7	53
1950	28	24	4	27.0	16.4	29.5	3.3	13.0	0	7.15	8.3	55
1952	27	15	3	30.0	21.0	32.0	4.4	12.5	0	7.2	8.2	55
1953	30	15	5	20.7	13.6	23.6	6.2	12.5	0	7.0	8.2	54

ECONOMICS OF UNIT WATER-PURIFICATION SYSTEMS

BY C. A. KNAPP*

[*Read October 6, 1954.*]

In the past, municipal and industrial water-treatment plants have usually consisted of two separate and distinct elements—pre-treatment units and rectangular rapid-sand filters. Now these two essential components have been combined to form the Dorrco Aldrich Peri-Filter System, a single and compact water-purification unit. In this system color, hardness, or turbidity is removed, and the precipitated solids are settled and thickened in the circular inner compartment. Residual suspended solids and bacteria are removed by the peripheral rapid-sand filter, surrounding the pre-treatment compartment.

This system was developed by E. H. Aldrich, Vice President and Chief Engineer of American Water Works Service Co., Inc., of Philadelphia, Pa. The design was originally motivated by the increasing cost of new plant construction. Consolidation of two major treatment steps in one unit showed marked economy not only in initial installed costs, but also in operating costs. In addition, the required land area was considerably less than for conventional units and such a design was readily adaptable to expansion, if increased plant capacity were required at some time in the future.

The first commercial installation was in a new plant for Alexandria, Va., in 1950. Design and construction of the plant, owned and operated by a subsidiary of American Water Works Service Co., was supervised by Mr. Aldrich. The units comprised a central baffled mixing and flocculation compartment, surrounded by a non-mechanically equipped settling chamber. The rapid-sand filter annularly enclosed the settling basin, which was designed so that mechanical equipment might be added at a future date.

In more recent installations a pre-treatment mechanism has been included, so that high-rate treatment methods and resulting smaller units may be employed. The initial cost of the mechanism has proved

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Note: PeriFilter, Hydro-Treator and Clariflocculator are registered trademarks of Dorr-Oliver, Inc.

more economical than the added construction costs of larger, non-mechanically equipped, low-rate units. Also, when treating surface water or water with a large amount of organic impurities, positive removal of solids is a necessity, as precipitated sludge may become septic in a short period of time, unless removed from the settling compartment. Continuous sludge removal also modifies the nuisance to the receiving stream. This latter advantage of mechanical equipment is frequently overlooked.

Shown in Figure 1 is a typical two-unit system; a concentric steel wall separates the two treatment sections and in operation serves as a weir, submerged six to twelve inches, over which treated water flows to the filter compartment. The filter section is further divided into two narrow concentric rings by a lower annular wall. The outermost ring contains the filter, while the lower ring is a sloping gullet to carry wash water to the drain during backwashing.

Also included in the system are filter bottom, gravel and sand, steel tanks and walkways, hydraulically- or motor-operated control valves, filter rate controllers, instruments and panel boards, necessary for manual or automatic operation and control. The hydraulic valves which regulate water flows in operation are sheltered in a small valve house adjacent to the treatment unit. One such house may serve as many as four individual units. Placement and number of valves required are clearly shown in the piping diagram (Fig. 2). In cases where adequate treated-water storage facilities are available, installation of a single unit will be sufficient. However, at least two units are usually recommended, to provide an uninterrupted flow of treated water during backwashing of one unit.

Normally, the pre-treatment mechanism is a Dorrco Hydro-Treator, a high-rate upflow unit, utilizing the sludge-blanket principle, as shown in Fig. 3. Flocculation, clarification and sludge thickening are carried out in three separate and distinct zones. It is particularly adaptable to softening, and removal of color and low or fine turbidity. Local conditions or the requirements of the specific purification problem may indicate the need for either a Dorrco Clariflocculator mechanism or a plain Clarifier.

The Dorrco Clariflocculator is a two-compartment unit, in which flocculation is carried out in the central section and continuous clari-

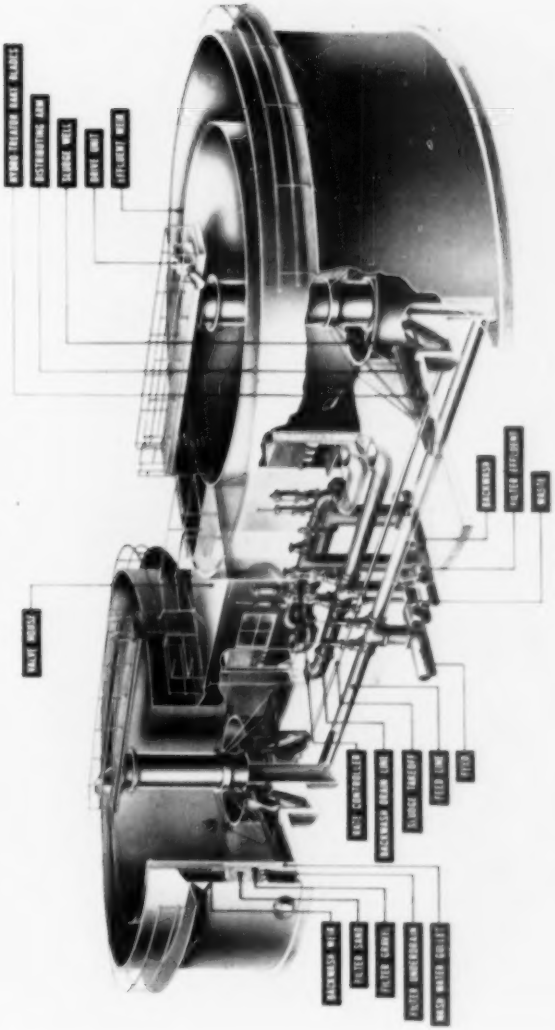

FIG. 1.—GENERAL ARRANGEMENT OF DORR-OLIVER PEBBLATOR SYSTEM

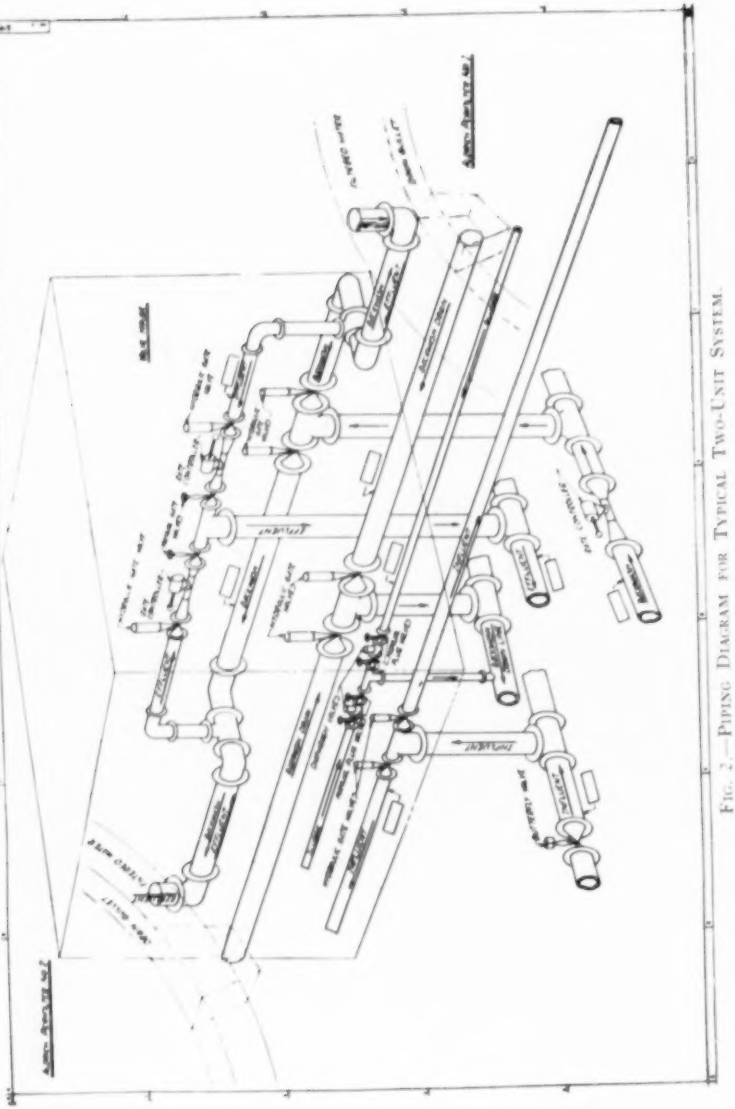

FIG. 2.—PIPING DIAGRAM FOR TYPICAL TWO-UNIT SYSTEM.

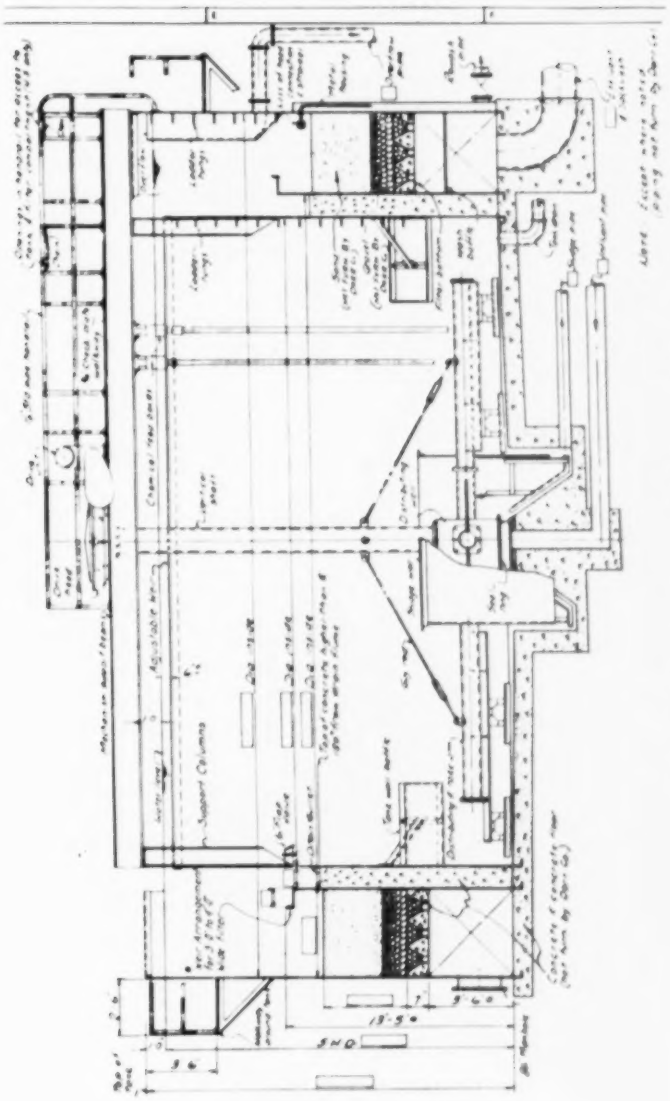

FIG. 5.—SECTIONAL ELEVATION OF SINGLE UNIT

fication and sedimentation of the coagulated solids in a surrounding chamber. It operates at conventional rates of flow and is amenable to high or coarse turbidity removal. The Clarifier is applicable only for the sedimentation of naturally flocculated solids or those chemically coagulated prior to pre-treatment. This variety of three mechanisms makes the PeriFilter System adaptable to all types of purification problems which may be encountered.

The annular rapid sand filter differs from conventional filters only in its peripheral placement with respect to the pre-treatment mechanism. Filter sand, usually 30 inches in static depth, rests upon a bed of graded gravel, one foot deep. Provision has been made to accommodate up to 36 in. of sand if desired. The gravel is supported by a filter bottom, or in some instances the sand rests directly on porous plates. Beneath this is a circular compartment, four feet deep, to collect treated water before it flows to chlorination or storage. Access to this space is through one or more 24-inch manholes. Details of both the filter and pre-treatment compartment are visible in the sectional elevation drawing of the tank.

The following sequence traces the operation of a system equipped with a high-rate upflow mechanism. Raw water entering through the feed pipe and mechanism center column is distributed evenly to the sludge blanket in the inner compartment through orifices in the revolving arms. Coagulating chemicals are usually introduced into the main raw-water pipeline before the water enters individual units. For certain conditions chemicals can be added directly into the sludge blanket of each unit.

The solids precipitated from or inherent in the feed are filtered out by the sludge blanket. They settle to the bottom of the tank and are raked to the central cone or sludge well by blades, attached to two of the four distributing arms. Here the solids are thickened and then pumped or discharged by hydrostatic head to waste.

Treated water flows upward in the central compartment and passes over the submerged weir to the filter. The water level is the same depth in both compartments. The depth of water over the filters, usually about eight feet, eliminates air binding in the sand filters. The flow of water across the submerged weir is extremely gentle, thus eliminating floc disintegration and turbulence, sometimes

produced in conventional plants by the transfer of water between treatment steps.

The rapid-sand filter removes any residual suspended solids and entrained bacteria, as the water passes through the sand and gravel into the collection compartment. The filter rate is regulated by the conventional rate controller on the effluent line. When the loss of head in the filter reaches a pre-determined limit—customarily 8 to 10 ft—the filter-backwashing cycle is begun, either manually or automatically.

This operation differs from backwashing of conventional rapid-sand filters only in that the pre-treatment unit must be shut down during this period. The feed is cut off and the filter compartment is partially drained through the effluent line, while the inner compartment remains filled with water. Backwash-water and drain lines are opened, and the effluent line is closed. Wash water is introduced slowly at first, to produce a scrubbing action in the sand bed, and then more rapidly to expand the filter bed. Surface washing of the sand can also be used if desirable. The wash water overflows the filter inwardly to the gullet and is carried to waste. When washing is completed, the sequence of valve operation is reversed and the unit returned to normal operation.

The PeriFilter System can be completely equipped with optional automatic controls, which will minimize operating attention and eliminate human error—unavoidably present in manual operation. The controls are usually located in the main control building or head-house, so that it is possible for a single operator to supervise the operation of all units, regardless of number. The major control guides the filter through the entire sequence of draining and backwashing, when manually actuated. This control is so designed that no step may begin until the previous step has been completed. Other controls regulate the rate of filtration and maintain constant water level in the tanks.

One feature differing from conventional plants is the elimination of the pipe gallery. Instead, the control valves are housed in a separate structure, located between units. This results in simplification of the piping and accessibility of the valves for maintenance.

The PeriFilter System is applicable to all types of municipal or industrial water-treatment problems. In New England, municipalities

and the chemical and pulp-and-paper industries are concerned chiefly with color, algae or tubidity removal and coagulation. However, this system may be used in addition for softening and iron or manganese removal.

To date no installations have been made in extremely cold climates and the only unit in New England is located at Greenwich, Conn. It is envisioned that where ice formation may be serious, the PeriFilter System may be enclosed in a semi-heated mill-type building, or the individual units may be covered separately. Chemical feeders and auxiliary equipment can also be housed under the same roof. In the past winter, units installed on the southern shores of Lake Erie experienced sub-freezing cold without incident. Minor ice formations were broken up during backwashing. Based upon this experience, future units in comparable climates need not be covered.

The PeriFilter System should be especially attractive for the production of 0.2 to 20 mgd of treated water. However, larger plants, composed of a number of units and accompanying valve houses, also show considerable economies. The design permits construction of a plant to handle only the immediate demand. Expansion to meet future demands is thus deferred until actually needed and is accomplished merely by the addition of more units. It is equally adaptable to new plant construction or expansion of existing plants of either the PeriFilter or conventional type.

Reductions up to 40% in initial installed costs over conventional-type plants have been achieved, as shown in Fig. 4. The cost figures from 34 new treatment plants have been plotted, to show the average cost per mgd of filter capacity. Data were obtained from 25 conventional plants, treating between 0.8 and 45 mgd, and from 9 of this new unit-type, processing between 2 and 13.5 mgd. Of the latter, those at Canonsburg, Pa., Monmouth, N. J., and Greenwich, Conn., are equipped with sludge-removal mechanisms. The first two mentioned employ Dorrco Hydro-Treator mechanisms. The actual savings, as shown, average approximately 40%.

As might be expected, strict correlation between the costs of the PeriFilter System and those of conventional design is extremely difficult. The variety of treatment required, the variations in design necessitated by local conditions, and the non-availability of complete

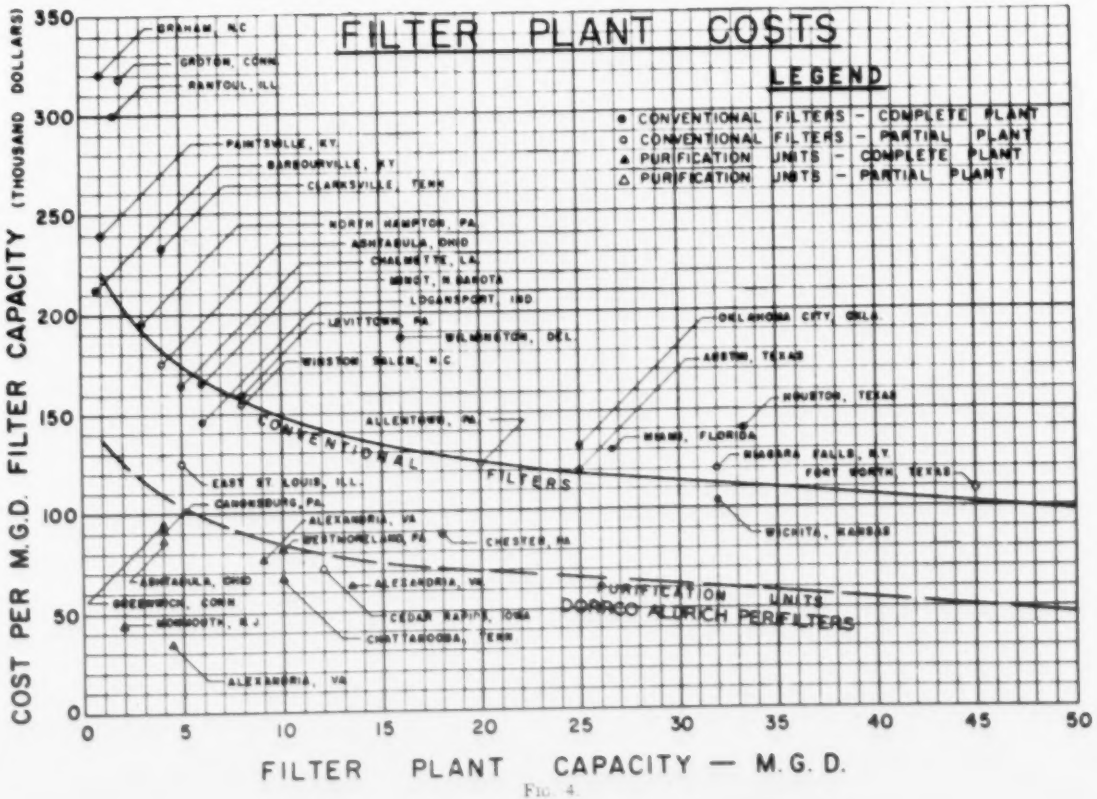
FILTER PLANT COSTS
LEGEND
CONVENTIONAL FILTERS - COMPLETE PLANT
CONVENTIONAL FILTERS - PARTIAL PLANT
PURIFICATION UNITS - COMPLETE PLANT
PURIFICATION UNITS - PARTIAL PLANT
COST PER M.G.D. FILTER CAPACITY (THOUSAND DOLLARS)
FILTER PLANT CAPACITY — M.G.D.
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
40
45
50
GRAHAM, N.C.
CROTON, CONN.
RANTOUL, ILL.
PAINTSVILLE, KY.
BARBOURVILLE, KY.
CLARKSVILLE, TENN.
NORTH HAMPTON, PA.
ASHTABULA, OHIO
CHALMETTE, LA.
MINOT, N. DAKOTA
LOGANSPORT, IND.
LEVITTOWN, PA.
WILMINGTON, DEL.
WINSTON SALEM, N.C.
ALLENTOWN, PA.
CONVENTIONAL FILTERS
EAST ST. LOUIS, ILL.
GETTYSBURG, PA.
ALEXANDRIA, VA.
WESTMORELAND, PA.
CHESTER, PA.
ASHTABULA, OHIO
GREENWICH, CONN.
MONMOUTH, N.J.
ALEXANDRIA, VA.
ALEXANDRIA, VA.
CEDAR RAPIDS, IOWA
CHATTANOOGA, TENN.
PURIFICATION UNITS
DORRCO ALDRICH PERFILTERS
OKLAHOMA CITY, OKLA.
ABILENE, TEXAS
HOUSTON, TEXAS
MIAMI, FLORIDA
NIAGARA FALLS, N.Y.
FORT WORTH, TEXAS
WICHITA, KANSAS

FIG. 4.

costs in a few instances make comparison difficult, except in a general manner. However, the curve, in its present form, serves as an excellent over-all indication of the reduced investment costs which may be expected in installations in which pre-treatment and filtration have been combined in a single unit.

Operating-labor costs of the various unit-type plants presently in operation have been low. The Alexandria treatment plant and high-service station, with a nominal capacity of 13.5 mgd, has an operating force of eight men: four operators, two maintenance men, a chemist and a chief engineer. All except the operators have other duties to perform. A similar force is employed at a second plant, where a low-service pumping station is operated by remote control. In two other instances, no additional operators were needed when plant capacity was increased by the construction of units of this type.

The logical consolidation of these two essential unit operations has been a big step toward the reduction of the initial cost of municipal and industrial water-treatment plants. The PeriFilter System has, in addition to decreasing construction and operating costs, shown marked design and operational advantages. It is readily adaptable, by virtue of its unit-construction feature, to expansion of either conventional plants or those of the same general type. The variety of available mechanisms makes it amenable to all types of treatment problems, and optional automatic control eliminates error and requires a minimum of attention.

SIMPLE FIELD METHODS FOR FINDING FIRE FLOW AND PIPE FRICTION

BY JOHN C. ADAMS, JR.*

[*Read at Superintendents' Round Table, Nov. 18, 1954.*]

A. Finding the Available Fire Flow

As superintendents, you know that periodically the National Board of Fire Underwriters or the New England Fire Insurance Rating Association sends field engineers to your town to make a survey of your system. Among other things, these engineers make flow tests at various locations in the system, in order to determine the ability of your system to deliver certain required fire flows. The results of these tests are included in the Underwriters' Report, in a table which shows the location tested, the fire flow required at the location, and the computed or calculated flow available.

The insurance engineers make only a few tests at critical locations. You may wish to make fire-flow tests at other areas or you may want to duplicate the insurance engineers' tests subsequent to some improvement in your system, to see what effects the improvements have made. It is the purpose of this discussion to demonstrate the method of making these tests and of calculating the results.

Before getting into the actual tests, it would be wise first to investigate how the "required fire flows" are established.

In general, the required fire-flow rate for any particular location is a matter of judgment on the part of the individual insurance engineer making the survey. They are, however, guided by the following, which is quoted from the National Fire Protection Association Handbook:

> "In the residential section of small cities and suburban areas of large cities where no congestion exists and where buildings are not high, approximately 500 Gals. Per Min. are needed.
>
> "Where the buildings are closer together, so that fire in one may spread to others (50 feet or less apart) 1000 Gals. Per Min. should be provided.

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"Where the district is closely built or buildings approach the dimensions of hotels or high-grade residences, 1500 Gals. Per Min. are required. Up to 6000 Gals. Per Min. may be required in densely built sections."

Experience shows that rarely do the insurance engineers establish a "required flow" of less than 1,000 gpm for any area.

The required fire flow must be met at some stated residual pressure. The residual pressure is that pressure remaining in the mains during the time that a flow test is taking place. This pressure is found by reading a pressure gage, attached to a hydrant which is not discharging, but which is located nearby and, if possible, on the side opposite to the direction from which the flow is coming. The National Board of Fire Underwriters usually decrees that the required fire flows be met at a residual pressure of 20 lb per sq in., where fire-engine pumpers are available.

Most of you are undoubtedly familiar with the various methods of measuring the discharge rate from a fire hydrant. A brief review of two of the simplest methods, however, would seem advisable.

The rate of discharge is determined from the following formula:

$$Q = C_D A V$$

where

Q = discharge rate;
C_D = coefficient of discharge;
A = area of the opening;
V = velocity of the stream or jet.

The area of the opening is, of course, readily obtained. The coefficient has been established experimentally for various openings or nozzles. The velocity, which must be measured, may be obtained by either of two simple methods.

a. *Hand Pitot*

A hand pitot tube with pressure gage may be held in the discharge stream, and the observed pressure reading is converted to gallons per minute of flow by use of tables. Many manufacturers provide tables for this purpose. In using the hand pitot, more accurate results are obtained if a nozzle is attached directly on the 2½-inch butt. The tables are arranged for various sizes of tips and various

pressures, and one has only to enter the tables to determine the flows. The National Board of Fire Underwriters has prepared an excellent handbook, entitled "Fire Engine Tests and Fire Stream Tables", which contains all the tables necessary for obtaining the discharge through various sizes of nozzles.

b. *Barrel Pressure*

Another method, a simpler one in that it requires no instrument other than a pressure gage, consists of placing an ordinary pressure gage on one 2½-inch butt and discharging the other 2½-inch butt. The pressure reading observed during the flow may be converted to the discharge rate in gpm from Table 1.

TABLE 1—FLOW IN GALLONS PER MINUTE THROUGH A 2½-INCH HYDRANT BUTT FOR VARIOUS BARREL PRESSURES

Barrel pressure (psi)	Flow (gpm)	Barrel pressure (psi)	Flow (gpm)
1	170	10	530
2	240	11	560
3	290	12	580
4	340	13	610
5	380	14	630
6	410	15	650
7	440	20	750
8	480	25	840
9	500	30	920

Note that this table is only good for discharge through a 2½ inch butt and should not be used if a nozzle has been attached.

Now as to making the actual test.—The location to be tested is first selected and the hydrants to be used are chosen. Let us assume a typical distribution system, as shown on Fig. 1. One hydrant is selected, away from the source, but at approximately the same elevation as the hydrants to be discharged. This hydrant is used for residual-pressure observations. The remaining hydrants, as many as necessary, are used to measure the discharge. Assume that Hydrant No. 1 in the sketch is used to measure the residual pressure.

First, the pressure at Hydrant No. 1 is observed with no hydrants discharging. This is the normal residual pressure in the system—that is, the residual pressure existing during a *no fire* condition.

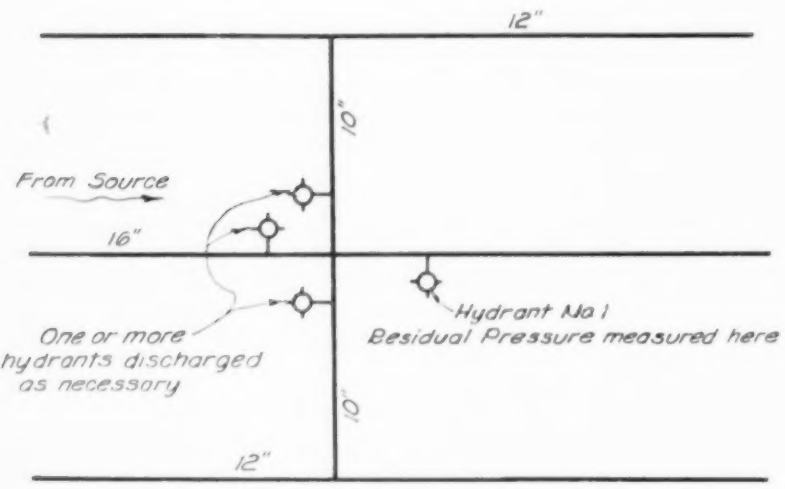


FIGURE -1

TYPICAL TEST FOR AVAILABLE FIRE FLOW

Next, one or more hydrants are opened and allowed to discharge. When the pressure at Hydrant No. 1 has stabilized, the discharge at each hydrant is then measured and totalled. The average residual pressure at Hydrant No. 1 during the flow measurements is also recorded

It would have been just chance if the total discharge had been exactly enough to produce a residual pressure at Hydrant No. 1 equal to 20 psi. It is nearly always necessary to correct the measured fire flow to that which would have been available at a residual pressure of 20 psi. This is done by the following formula:

$$Q_A = Q_T \frac{(P_O - 20)^{0.54}}{(P_O - P_T)^{0.54}}$$

Where

Q_T = the sum of the measured discharge at each hydrant flowed.

Q_A = the available fire flow for the location at a residual pressure of 20 psi.

P_O = the residual pressure in the system at the location during *no fire flow* conditions. P_O is the pressure observed at Hydrant No. 1 before any of the other hydrants are opened.

P_T = the residual pressure during the test. P_T is the pressure observed at Hydrant No. 1 while the other hydrants are being discharged.

The values of $(P_O - 20)^{0.54}$ and $(P_O - P_T)^{0.54}$ may be obtained from Table 2.

TABLE 2—THE 0.54 POWER OF NUMBERS—$(N)^{0.54}$

N	0	1	2	3	4	5	6	7	8	9
0	0.0	1.0	1.5	1.8	2.1	2.4	2.6	2.9	3.1	3.3
10	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.6	4.8	4.9
20	5.1	5.2	5.3	5.4	5.6	5.7	5.8	5.9	6.1	6.2
30	6.3	6.4	6.5	6.6	6.7	6.8	7.0	7.1	7.2	7.3
40	7.4	7.5	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2
50	8.3	8.4	8.5	8.6	8.6	8.7	8.8	8.9	9.0	9.1
60	9.1	9.2	9.3	9.4	9.5	9.5	9.6	9.7	9.8	9.9
70	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.5	10.6	10.6
80	10.7	10.8	10.8	10.9	11.0	11.0	11.1	11.2	11.3	11.3
90	11.4	11.4	11.5	11.5	11.6	11.7	11.8	11.8	11.9	11.9

The following example will serve to clarify the computations involved:

Example 1

Assume:

1. The observed residual pressure at Hydrant No. 1 prior to discharging the other hydrants is 90 lb per sq in.

2. The observed residual pressure at Hydrant No. 1 during a total discharge through the other hydrants of 1,800 gpm is 40 lb per sq in.

Substituting these data in the equation:

$$Q_A = Q_T \frac{(P_O - 20)^{0.54}}{(P_O - P_T)^{0.54}}$$

we get

$$Q_A = (1800)\,\frac{(90 - 20)^{0.54}}{(90 - 40)^{0.54}}$$

and from Table 2,

$$(90 - 20)^{0.54} = (70)^{0.54} = 9.9$$

and

$$(90 - 40)^{0.54} = (50)^{0.54} = 8.3$$

therefore,

$$Q_A = (1800)\,\frac{(9.9)}{(8.3)}$$

and

$$Q_A = 2{,}070 \text{ gpm.}$$

In other words, at 20 lb per sq in., a fire flow of 2,070 gpm would be available at this location.

B. Finding the Pipe Friction Coefficient

There are many formulas for computing the friction loss in a pipe for various flows, of which the most widely used in water-works engineering is the Hazen-Williams formula. One of the important factors in this formula is the coefficient of the pipe, or "*C*" value. This factor, "*C*", is a function of the condition of the interior of the pipe, its roughness and resistance to flow. The "*C*" value of a pipe has, through the years, come to be a measure of the condition of a given pipe. If a given pipe has a "*C*" value of 115, we know that it is a fairly new main, in good condition. Conversely, a pipe having a "*C*" value of 60 is fairly old and will show high head losses.

New pipe has a "*C*" value ranging from 120 to 140, depending upon the type of lining. After pipe has been in service a number of years, the "*C*" value decreases. The rate at which it decreases, however, is dependent upon many factors, such as the quality of water and/or type of lining. Highly corrosive waters will decrease the "*C*" value rapidly. One of the most difficult problems facing the engineer is what "*C*" value to assign to a pipe which has been in service for several years. It is, of course, possible to make educated guesses, but the best method is actually to test the pipe and determine the "*C*" value. There are several methods by which this can be done. It is

the purpose here to describe one of the more simple methods for testing and computing the "C" values of mains which have been in service for some time.

The first step is to select a section of the main which can be isolated by valving. The reach should be at least 2,000 ft long and preferably longer. Care must be taken in valving off the main from other parts of the system, so that no area is completely isolated from a source of water, if possible. Assume a sample area in a distribution system, such as is shown on Fig. 2. The 12-inch main is to be tested and it is isolated by closing the indicated valves. Note that no portion of the system is without water. Water can enter the main to be tested at one end only. It is advisable during the actual test to request customers served off the main being tested to refrain from using water during the test operations, usually a few minutes.

Two hydrants, Numbers 1 and 2, are selected as far as possible apart. The distance between the hydrants (L) is measured. Pres-

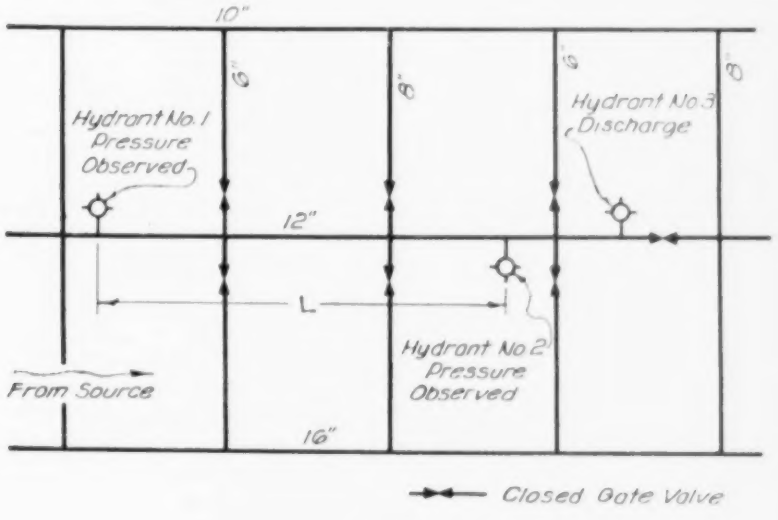


FIGURE -2

TYPICAL TEST FOR PIPE COEFFICIENT

sure gages are attached to Hydrants 1 and 2 and the elevations of the centers of these pressure gages are obtained by survey.

An observer is stationed at each of the Hydrants, 1, 2 and 3. Each man has a watch, all synchronized to the same time. Hydrant No. 3 is discharged. At prearranged times, simultaneous readings of pressure at Hydrants 1 and 2 and of flow at Hydrant 3 are obtained. The flow at Hydrant 3 may be obtained by one of the methods described previously. Usually 5 sets of readings at intervals of one minute are sufficient.

The first step in computing the "*C*" value is to correct the observed pressures P_1 and P_2 to true pressures. This means merely correcting for the gage error. Gages used for these tests should be calibrated against dead-weight machines. Once the true pressures P_1 and P_2 are known, the following computation is made:

Elevation of center of gage at Hydrant 1 =
$P_1 \times 2.31$ = _____
Total pressure head at Hydrant 1 (H_1) =

Elevation of center of gage at Hydrant 2 =
$P_2 \times 2.31$ = _____
Total pressure head at Hydrant 2 (H_2) =

The difference between the two total heads, $H_1 - H_2$, is then divided by the number of thousands of feet between the Hydrants 1 and 2. This gives the head loss in the main in feet per thousand feet.

$$h_f = \frac{H_1 - H_2}{L}$$

where h_f = head loss in feet per thousand feet
H_1 = total pressure head at Hydrant No. 1
H_2 = total pressure head at Hydrant No. 2
L = distance between the hydrants in thousands of feet.

The discharge at Hydrant No. 3 (Q), having been measured, is because of the valving, the flow in the pipe. Knowing this Q and the diameter of the pipe, the "*C*" value can be calculated in a number of ways. Various nomographs, charts, tables or slide rules have been prepared which give the Q, the h_f, the diameter, and the "*C*" value. If any three of these are known, by use of these tables, nomographs

or slide rules, the fourth can be determined, or the following formula may be used:

$$C = \frac{(Q)\ (150)}{(D^{2.63})\ (h_f)^{0.54}}$$

where C = pipe friction coefficient
Q = flow in pipe in gpm
D = Diameter of pipe in inches
h_f = head loss in the pipe in feet per thousand feet.

If the size of the main—that is, the diameter (D)—is known, the value of $D^{2.63}$ may be obtained from Table 3. The value of h_f having been computed as previously outlined, the value of $(h_f)^{0.54}$ may be obtained from Table 2.

TABLE 3—VALES OF $(D^{2.63})$

D	$D^{2.63}$
6	111
8	237
10	427
12	689
16	1,468
20	2,640
24	4,265
30	7,670
36	12,390

The following example will serve to illustrate the calculations involved:

Example 2

Assume:

Elevation of Hydrant No. 1	=	160 ft
True pressure at Hydrant No. 1	=	82 psi
Elevation of Hydrant No. 2	=	150 ft
True pressure at Hydrant No. 2	=	75 psi
Distance between Hydrants 1 and 2 (L)	=	3,125 ft
Diameter of pipe	=	12 in.
Total flow at Hydrant No. 3	=	1,000 gpm

Total pressure head at Hydrant No. 1

$(H_1) = 160 + (82 \times 2.31) = 349.8$ ft

Total pressure head at Hydrant No. 2

$(H_2) = 150 + (75 \times 2.31) = 323.5$ ft

$H_1 - H_2 \qquad 26.3$ ft

and $h_f = \dfrac{H_1 - H_2}{L} = \dfrac{26.3}{3.125} = 8.45$ ft per 1,000 ft.

From Table 3, $D^{2.63}$ for a 12-inch pipe is 689. From Table 2, $h_f^{0.54}$ for an $h_f = 8.45$ is 3.2.

Substituting these values in the expression,

$$C = \frac{(Q_{gpm})\ (150)}{(D^{2.63})\ (h_f)^{0.54}}$$

we get $$C = \frac{(1{,}000)\ (150)}{(689)\ (3.2)}$$

or $$C = 68.2$$

REVIEW OF MICROÖRGANISMS IN WATER SUPPLIES

BY SAMUEL O. SWARTZ*

[*Read at Chemists' Round Table, Nov. 18, 1954.*]

The occurrence of odors and tastes in water supplies may be due to the presence of minerals, organic matter or gases, dissolved by the contact of the water with decayed vegetable matter from swampy areas, and the growth of aquatic plants and microscopic organisms. The impounding of water in reservoirs makes it subject to growths of microscopic organisms, which are minute plants and animal life, too small to be visible to the naked eye. In large numbers the organisms may impart a distinct green or blue-green color to a reservoir or a pond.

Microscopical organisms are the most common cause of objectionable taste and odor in surface waters or in ground waters stored in open reservoirs for extended periods of time. These organisms, upon decay, give off minute particles of odor-producing oils. Some of these odors may be described as aromatic, grassy, fishy or characteristic of flowers, such as violets, geraniums or nasturtiums; also cucumbers and moss.

Microörganisms are also referred to as algae or plankton, and the free-floating forms of life include numerous varieties which thrive throughout the season of the year, depending on sunlight for their existence, together with the amount of dissolved oxygen and free carbonic acid which is the controlling influence on the presence of microscopic organisms.

The Algae are chlorophyll-containing, unicellular or multicellular organisms, which are usually green or blue-green in color, but some forms contain brown or red coloring matter.

The Fungi group does not contain chlorophyll and is not dependent on sunlight for its existence. The organisms are usually grey in color or brown when iron is accumulated. Fungal growths may flourish in the dark, such as at the bottom of reservoirs or in pipelines of a distribution system.

*Senior Bacteriologist, Water Division, Metropolitan District Commission, 20 Somerset St., Boston, Mass.

The most common forms which cause trouble in public water supplies are the iron bacteria, such as: *Crenothrix, Leptothrix* and *Gallionella.*

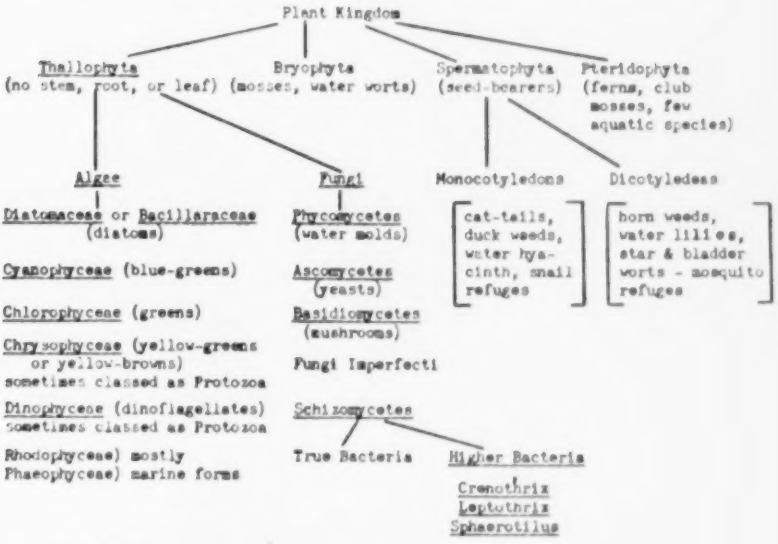
Water-supply personnel are concerned only with eliminating or controlling troublesome algae. Taste and odor control can be gained by determining the presence of undesirable organisms and treating chemically to eradicate the condition.

The classification of plankton sometimes becomes an academic problem, so that water-works operators are required to find the services of a biologist who is trained in this field to assist with the work.

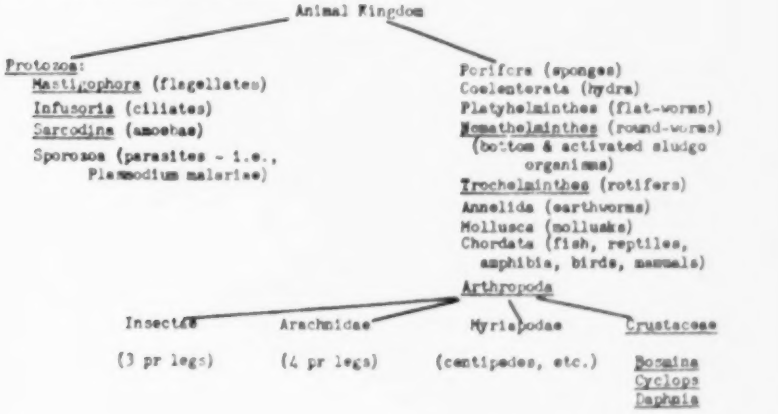
The microörganisms with which we are concerned are too numerous to mention at this time. A descriptive outline of the most common forms of microörganisms, which give rise to odors and taste complaints, is as follows:

CLASSIFICATION OF PLANKTON

I. Phytoplankton - Plant Kingdom



II. Zoöplankton - Animal Kingdom



Algae Chart

Copyright - 1949

Microscopic Organisms In Water Supplies

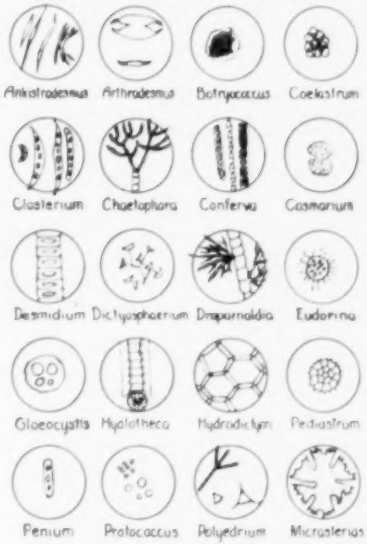
By Samuel O. Swartz

Bacteriologist - Metropolitan Water, Boston Mass.

DIATOMACEÆ

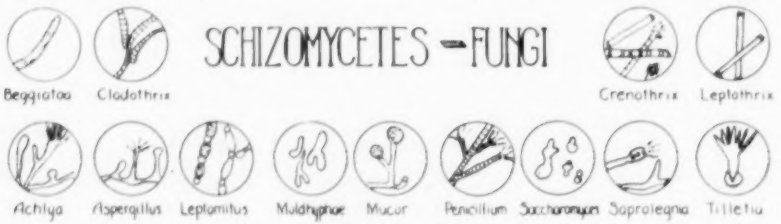
CYANOPHYCEÆ

CHLOROPHYCEÆ



PROTOZOA

SCHIZOMYCETES — FUNGI



ROTIFERA

CRUSTACEA

MISCELLANEOUS

Algae Frequently Found in Water Supplies

Diatomaceae

Amphora
*Asterionella
*Cyclotella
Cymbella
*Diatoma
Eunotia
*Fragilaria
*Gomphonema
*Melosira
Meridion
*Navicula
Nitzchia
Pinnularia
*Pleurosigma
Pleurostauron
*Stephanodiscus
*Surirella
*Synedra
*Tabellaria

Cyanophyceae

*Anabaena
*Aphanizomenon
*Coelosphaerium
*Gleocapsa
Lyngbia
Merismopedia
*Mycrocystis
Nostoc
*Oscillatoria

Chlorophyceae

*Ankistrodesmus
Arthrodesmus
*Chaetophora
*Chara
*Chlamydomonas
*Chlorella
Chlorococcum
*Chladophora
*Closterium
*Coelastrum
*Cosmarium
*Dictyosphaerium
*Draparnaldia
*Eudorina
*Gonium
Hyalotheca
*Hydrodictyon
*Micrasterias
*Mougeotia
*Oedogonium
*Pandorina
*Pediastrum
*Penium
*Scenedesmus
Sorastrum
*Spirogyra
*Staurastrum
*Stigeoclonium
Tetmemorus
*Tetraspora
Tribonema
*Ulothrix
*Volvox
*Xanthidium
*Zygnema

Protozoa

*Actinophrys
*Amoeba
*Arcella
Bursaria
*Carchesium
Chilodon
Coleps
*Colpidium
*Colpoda
Didinium
Difflugia
*Epistylis
Euglypha
Euplotes
*Frontonia
*Holosticha
Loxophyllum
Nassula
*Opercularia
*Paramecium
*Stentor
*Stylonychia
Uroleptus
*Vorticella
Zoöthamnion

Chrysophyceae

*Ceratium
*Cryptomonas
*Dinobryon
*Euglena
*Glenodinium
*Mallomonas
*Peridinium
*Phacus
Syncripta
*Synura
*Uroglena

Crustacea

*Bosmina
Ceriodaphnia
*Cyclops
Cypris
*Daphnia
*Diaptomus
*Limnocalanus

Rotifera

*Anurea
Brachionus
Diaschiza
*Notholca
Notops
*Philodina
Synchaeta
Triarthra

Schizomycetes

Beggiatoa
Cladothrix
Crenothrix
Leptothrix

Fungi

Achlya
Aspergillus
Leptomitus
Moldhyphae
Mucor
Penicillium
Saccharomyces
Saprolegnia
Tilletia

Characteristics of Diatomaceae
(*Diatoms*)

Diatoms consist of box-like siliceous cells in 2 halves, called the upper and lower valves. Differentiation is based upon the shape and ornamentation of the valves. All the diatoms contain chlorophyll, so that live ones appear green-tinted. They are all motile by means of protoplasmic flow. Reproduction is usually by separation of the valves. Both single and colonial forms occur.

Diatoms are cold-water organisms, their temperature optimum being 40°-60° F. They are generally most prominent just after the spring overturn and usually prefer clean water. Several types are known to produce odor trouble in water. The odors range from aromatic to fishy. A few complaints are registered at concentrations of 2,000 standard units per cc or above.

Important Genera

Asterionella: wheel-spokes—a common offender—geranium to fishy odors.
Synedra: a common offender—earthy odors—3 species.
Ulna: single spikes.
Pulchella: comb-like.
Radians: star-shaped.
Tabellaria: joined platelets—fishy odor in large numbers.
Melosira: staked pill-boxes—oily tastes.
Meridion: forms arches—aromatic odors.
Fragillaria: stacked pill-boxes.
Navicula: boat-shaped—not offensive.
Stephanodiscus: large pie plates.

Characteristics of Cyanophyceae
(*Blue-Green Algae*)

These are the most primitive of the fresh-water algae. They are pigmented, varying from blue-green to reddish-brown in color, depending on age or condition, but have no distinct chromatophores. Ordinarily, they are non-motile and have no flagella. Common forms are cells in a gelatinous matrix or in filaments. They reproduce entirely by fission.

The blue-greens are primarily warm-weather organisms. The general temperature optimum is 60°-80° F., though there is considerable variation for different genera. Greatest concentrations are normally found in August and September. Odors produced are grassy or mouldy in low concentrations and pigpen in high concentrations.

Important Genera

Anabaena: string of beads—large beads reproductive cells. This is a very bad offender—pigpen odor at about 600 standard units per cc. It is one of algae which produces a toxin. Sheep and cattle have been killed by drinking water containing heavy growths and humans have been made ill.

Aphanizomenon: similar to *Anabaena,* but filaments are more slender and less well differentiated into beads. Odor troubles and toxin production similar to *Anabaena.*

Nostoc: similar to *Anabaena,* but encased in a gelatinous mass—not so common.

Microcystis: small, colonial green cells in spherical clusters—also a toxin-producer—not very troublesome.

Clathrocystis: similar to *Microcystis,* except that colonies are likely to be hollow or perforated.

Coelospherium: practically same as previous two.

Oscillatoria: long smooth filaments, composed of rectangular cells—quite common, but usually attached—seldom troublesome unless it breaks loose. This is one of few motile blue-greens. It shows a wide variation in size and color—from green to brown filaments.

Characteristics of Chlorophyceae
(*Green Algae*)

These predominantly green organisms are the most highly developed algae. They are highly variable in form and the number of species is very large. They are differentiated from the blue-greens by the presence of a definite nucleus and well-defined chloroplasts.

These are moderate-temperature organisms in general—optimum temperatures 50°-70° F. They are most active photosynthetically of all algae. Although many species are generally observed in water samples, the class rarely predominates. Only a few types are trouble-

some and then only at high concentrations. The odors produced are grassy, nasturtium.

Important Genera

I. *Desmids:* solitary cellular type, composed of hemicells which are mirror images. Prefer moderately polluted water.

Closterium: crescent moon—common, especially in nitrified sewage-treatment effluents.

Staurastrum: paired triangles.

Cosmarium: hour glass.

II. *Non-Filamentous Forms.*

Eudorina:	Spherical gelatinous matrices
Pandorina:	with spherical chloroplasts.
Volvox:	These are offenders, giving fishy tastes.

Dictyospherium: green jelly-beans in a spherical gelatinous matrix. This is probably worst offender among chlorophyceae. Gives grassy to nasturtium to fishy odors.

Pediastrum: toothed wheel.

Hydrodictyon: water net—a bad offender.

Scenedesmus: very common—likes slightly polluted water.

III. *Filamentous Forms.*

Spirogyra: transparent filament with spiral chloroplasts—clogs filters.

Zygnema: multicellular filaments with 2 chloroplasts in each cell.

Ulothrix: rectangular cells, arranged in filament, surrounded by gelatinous sheath.

CHARACTERISTICS OF CHRYSOPHYCEAE
(Yellow-Green Algae)

These are yellow to green, flagellated, motile algae, which are sometimes classed with the protozoa.

They are very cold-water organisms and will even grow in contact with ice. Their optimum range is 40°-50° F. Generally, they are most abundant in early spring. Many of these cause troubles in water supplies; they are probably the worst group of offenders. The odors produced vary from vegetable to cod-liver-oil and are noticeable at low concentrations of organisms.

Important Genera

Synura: bunch of grapes with 2 flagella on each grape—grows from 32° F. up. Produces a cucumber taste when hardly detectable by microscopic methods—strong cod-liver-oil tastes from 100 standard units per cc.

Uroglenopsis: large spherical matrix, containing green cells, each with 2 flagella. A delicate organism, seldom found whole unless water is examined immediately. Gives fishy, cod-liver-oil tastes with only 3 to 4 colonies per liter.

Dinobryon: branched cups with 2 flagella per cup. Gives aromatic to fishy odors.

Mallomonas: small spiny organism with a single long flagellum—not so troublesome.

Characteristics of Dinophyceae (*Dinoflagellates*)

These are yellowish to brown organisms with covering of cellulose plates. They have 2 flagella in the center of the organisms and have erratic motility.

No temperature optimum for these organisms is known. They are likely to occur at any time and produce fishy taste and odors.

Important Genera

Ceratium: turkey-foot—produces a rust-brown color and strong fish odor to a "vile stench."

Peridinium: walnut shells with a constricted band in between—fishy odor.

Glenodinium: divided egg-shell—fishy odor.

Characteristics of Protozoa

These are unicellular animals. They require organic matter for nutrition and do not contain chlorophyll. They are motile. These organisms do not cause trouble in water supplies, but are used as pollution indicators. They are found extensively in sewage and activated sludge. A few of the forms are parasitic and pathogenic.

Important Genera

I. *Sarcodinae* (amoebae)

A. *Rhizopods:* (root-footed organisms)
Amoeba: blobs with heavy protuberances.
Arcella: } Have shells with protuberances
Difflugia: } emerging from beneath them.

B. *Actinopods:* spine-footed organisms.
Actinophys: pin cushion.

II. *Mastigophora* (flagellates). Most of the important forms are those which have been classified as yellow-green algae or dino-flagellates. Some of the forms are:

Monas: very small, unpigmented cell.

Anthophysa: spherical bunch of white cells, each with 2 flagella, all on a brown stalk.

Peranema: spindle with spiral flagellum.

III. *Infusoria or Ciliata* (ciliates). These are most complex of protozoa. They have gullets and anal openings. Highly motile. Bacteria-eaters.

Paramecium: slipper-shaped.

Vorticella: morning-glory with stalk.

Carchesium: like *Vorticella*, but stalk cannot be contracted.

Stentor: trumpet, attached at foot.

Colpidium: fig-shaped.

Coleps: hand grenade.

Euglena: sometimes classified by itself, sometimes with protozoa or other groups. Bright green, slug-shaped, with red eye-spot and a single flagellum, extending in direction of motion. Weaves through the water.

OTHER FORMS OF MICROSCOPIC ORGANISMS

I. *Trochelminthes* (rotifers). These are the smallest multi-celled animals. They are characterized by a fringe of cilia around the mouth. They feed on algae. They may either be free-swimming or attached at the foot. Except for a few common genera, the rotifers are not routinely classified.

Important Genera

Anuraea—Conochilus—Polyarthra—Rotifer.

II. *Crustaceae.* These are also multicelled animals and algae eaters. They have articulated shells and the common types observed in water microscopy are large enough so that they are barely visible to the naked eye.

Important Genera

Bosmina—Daphnia—Cyclops—Nauplius.

These are sometimes referred to as water-fleas.

III. *Higher Bacteria.* Several types of higher bacteria, which tend to be filamentous, are of importance in water microscopy. They belong to the groups called the iron bacteria and sulfur bacteria.

Among them are:

Sphaerotilus Natans: This genus grows in colorless threads, comprised of rod or oval cells, surrounded by a thin firm sheath. No true branching is shown. The filaments tend to aggregate in tufts, visible to the eye, on the bottom or surfaces of streams. The organisms prefer polluted water and the grey tufts, which wave in the currents, are one of the characteristic visible indices of pollution.

Leptothrix: These organisms show filaments of colorless, cylindrical cells, which are often incrusted with iron oxide.

Crenothrix: These form single, sheathed filaments, containing cylindrical or spherical cells. When the organisms are young, the sheaths, though clearly visible, are colorless. Old filaments become brown with deposited iron oxide.

Gallionella: These are also iron bacteria. They utilize ferrous iron for nutrition and are observed as twisted filaments, often entwined in pairs.

These four genera are all classified as iron bacteria and tend to grow and clog water mains.

Beggiatoa: These are the higher sulfur bacteria and form colorless filaments, containing numerous, dark, sulfur granules. These are motile and exhibit an oscillating motion. The true sulfur bacteria are not observed in routine microscopic examinations of water.

IV. *Miscellaneous.* Organisms frequently found in sewage, sludge or bottom deposits:

Nematode Worms: (vinegar eels)
Tubifex: (bristle-bearing annelid worms)
Eristalis Tenax: (the rat-tailed maggot)
Chironomids: (red or yellow insect larvae)

Microscopic organisms are not believed to be dangerous to public health, but they do cause many consumer complaints. Taste and odors caused by algae may be removed or prevented by the use of copper-sulphate treatment or chlorination. The control or elimination of algae nuisances, thus far, is temporary and requires the constant vigilance of the water-supply personnel.

Reference

"The Microscopy of Drinking Water," by George C. Whipple. John Wiley & Sons, New York.

PROCEEDINGS

FEBRUARY 1955 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, FEBRUARY 17, 1955

President Roger G. Oakman in the Chair.

Secretary Knox announced the election of the following to membership in the Association:

James R. Caron, Accountant, Portland Water District, Portland, Me.; Franklin M. Gifford, Jr., Superintendent, Water Department, Cotuit, Mass.; Ralph K. Goodwin, U. S. Pipe & Foundry Co., Boston, Mass.; Arthur Wilbur Cambridge, Superintendent, Holbrook Water Department, Holbrook, Mass.; Earle L. Pike, President, Wakefield Water Co., Narragansett, R. I.

Papers on the general subject of "Maintenance of Steel Water-Works Tanks" were read as follows:

"Introducing the Problem." George A. Sampson, Partner, Weston & Sampson, Engineers, Boston, Mass.

"The Superintendents' Problem." Allan M. Symonds, Engineer, General Engineering & Construction Co., Boston, Mass.

"Tank Paint Manufacturers' Problems." Charles J. Gotthardt, Vice-President, E. & F. King Co., Norwood, Mass.

"The Painting Contractors' Problem." Frank A. Crosby for Roy O. Leonard, Contractor, Framingham, Mass.

March 1955 Meeting

Hotel Statler, Boston, Mass.

Thursday, March 17, 1955

President Roger G. Oakman in the Chair.

Secretary Knox announced the election of the following to membership in the Association:

Raymond W. Anderson, Supervisor, Transmission and Distribution, Water Department, Pawtucket, R. I.; William F. Foubey, General Foreman, Water Department, Salem, Mass.; Russell J. Lutz, Superintendent of Public Works, Sharon, Mass.; John S. B. Morrison, Chemist, Simplex Wire & Cable Co., Cambridge, Mass.; Walter A. Clark, Superintendent, Water Department, Burlington, Mass.

Associate Members

Angro Painting Service, Natick, Mass.; Simplex Wire & Cable Co., Cambridge, Mass.

Upon motion of Richard H. Ellis, duly seconded, it was Voted that the last five past-presidents, exclusive of those serving on the Executive Committee, serve as members of the Nominating Committee. These men are as follows: Donald C. Calderwood, Arthur C. King, Sidney S. Anthony, Thomas R. Camp and Frederick O. A. Almquist, with Mr. Anthony serving as Chairman.

An illustrated paper on "Microstrainers in Water Purification" was read by Dr. P. L. Boucher, Consulting Engineer, Glenfield and Kennedy, Ltd., Kilmarnock, Scotland.

A paper on "Improvements in the Fitchburg Water System" was read by Thomas E. Kennedy, Superintendent and Registrar, Water Department, Fitchburg, Mass.

Edwin B. Cobb, Partner, Metcalf & Eddy, Engineers, Boston, Mass., gave an illustrated talk on "The Analysis of Complex Water-Works Distribution Networks."

INTERIM REPORT OF COMMITTEE ON METHODS OF FINANCING WATER-MAIN EXTENSIONS—TABULATION OF DATA RECEIVED FROM MEMBERS OF THE ASSOCIATION

April, 1955

Method of Payment	*Population Groups*	Under 10,000			10,000 to 25,000			25,000 to 50,000			50,000 to 100,000			Over 100,000			
	Number Reporting	71			46			20			9			11			157
	Type and % of Total in Each Group	*Public*	*Private*	*%*	*Public*	*Private*	*%*	*Public*	*Private*	*%*	*Public*	*Private*	*%*	*Public*	*Private*	*%*	
(1) New Developments																	
By Developer		29	4	47	22	3	54	5	0	26	0	0	0	2	0	18	
Town Appropriation or Bond Issue or Company		10	2	17	4	0	9	4	1	26	3	1	45	4	0	36	
Guarantee Basis—4% to 12% from 5 to 20 Years		9	3	17	8	1	20	3	1	21	3	0	33	1	2	27	
Each Pay ½		2		3	1			1									
Owner Excavate—City Pipe					1			2			1						
Owner for 6"—Dept. Difference for Larger Size					1												
75% of Revenue for 15 Years or Until Paid					1												
Reimbursement When Revenue Is 10% of Cost								1									
Refund 3 × 1st Year's Revenue from Each Service		1															
Deposit Full Amount, 3½ × Revenue of Each Taker Refunded									1								
$5.00 Foot—Reimbursed $225.00 Each Customer					1												
Owner Pays $2.50 Linear Foot														2		18	
Abuttors Pay $2.35 Front Foot								1									
Owner Pays $3.00 Foot					1												
Company Pays 50 Ft. of 8" or 80 Ft. 2" for Each Service. Owner Pays Difference. Refund of $120 Ea. Add. Service to Amt. of Deposit for 10 Years											1						
No Policy or Under Consideration		9	2	16	1	1	4										

INTERIM REPORT OF COMMITTEE ON METHODS OF FINANCING WATER-MAIN EXTENSIONS—TABULATION OF DATA RECEIVED

Service to Amt. of Deposit for 10 Years																
No Policy or Under Consideration	9	2	16	1	1	4										

INTERIM REPORT OF COMMITTEE ON METHODS OF FINANCING WATER-MAIN EXTENSIONS—TABULATION OF DATA RECEIVED FROM MEMBERS OF THE ASSOCIATION (*Continued*) April, 1955

Method of Payment	*Population Groups*	Under 10,000			10,000 to 25,000			25,000 to 50,000			50,000 to 100,000			Over 100,000			
	Number Reporting	66			47			19			9			10			151
	Type and % of Total in Each Group	*Public*	*Private*	*%*	*Public*	*Private*	*%*	*Public*	*Private*	*%*	*Public*	*Private*	*%*	*Public*	*Private*	*%*	
(2) On Accepted Streets																	
By Developer		7		10	5	1	13							1		10	
Town Appropriation—Bond Issue or Company Pays		33	3	55	19	3	45	7	1	42	4	1	56	4	0	40	
Guarantee Basis 5% to 10% from 5 to 20 Years		12	2	21	9	1	21	5		16	3		33		2	20	
Each Pay ½		2		3				1									
Owner ½ over 20 Years					1												
Owner ½ over 10 Years					1			1									
Reimbursed When Revenue is 10% of Cost								1									
75% of Revenue for 15 Years or Until Paid					1												
Refund 3 × 1st Year's Revenue from Each Service		1				1											
Deposit Full Amount, 3½ × Revenue of Each Taker Refunded									1								
Betterment		1															
Acc. to Frontage		1			3		6							1			
Pay $2.50 Linear Foot								1						2			
Abuttors Pay $2.35 Front Foot					1												
$1.50 Front Foot—Minimum 75 Feet					2		4										
50 Feet Each Service—Refund $120.00												1					
100 Feet Free for Each Unit, above That 5% for 10 Years or Until Other Takers		1															
50 Feet Free for Each Service—$2.00 Ft. above That Plus Ledge					1			1									
No Policy or Under Consideration		1	2	4													
If Estimated Revenue for 5 Years Is Less than Cost, Difference Is Assessed against Abuttors on Front-Foot Basis					1												

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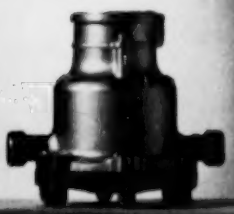

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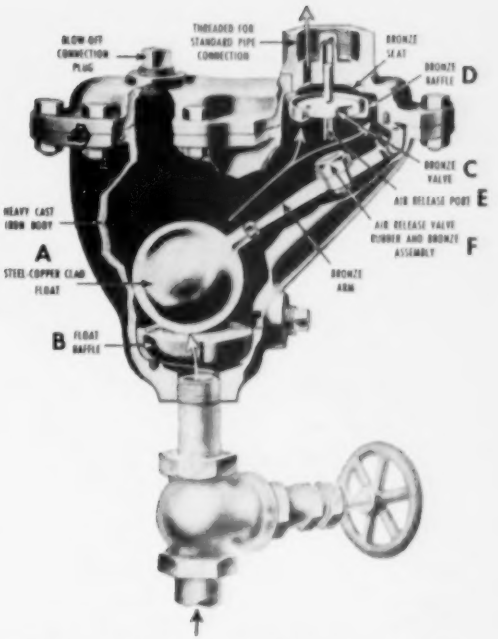

This Rensselaer valve is used to allow air to escape while the pipe is being filled with water; to allow air to flow into the pipe when it is being emptied of water and to allow accumulated air under pressure to escape at high points of the line.

It is used extensively for water mains, turbine pump discharge, bowls of booster pumps, air tanks and sand traps.

This valve will positively close under low water head, cannot blow shut and allows full and clear passage of air.

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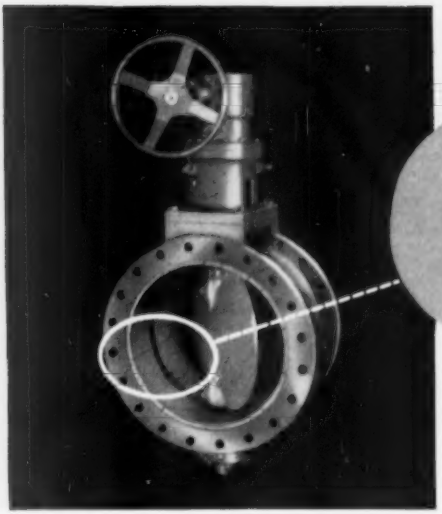
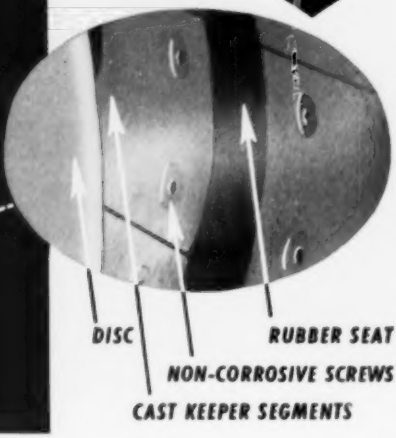


HERE'S WHY



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Chosen in the East. This photograph shows "Century" Pipe being laid in the hard, rock-filled soil of New England near South Hadley Falls, Mass. Today, more and more value-conscious communities are specifying this durable, long-lasting pipe.

13 miles of long-lasting pipe! Pictured here is part of a 13-mile installation of "Century" Pipe at the Lakewood Water District near Tacoma, Washington. Made of two practically indestructible materials, asbestos and cement, "Century" Pipe assures *extra* years of low-cost service.

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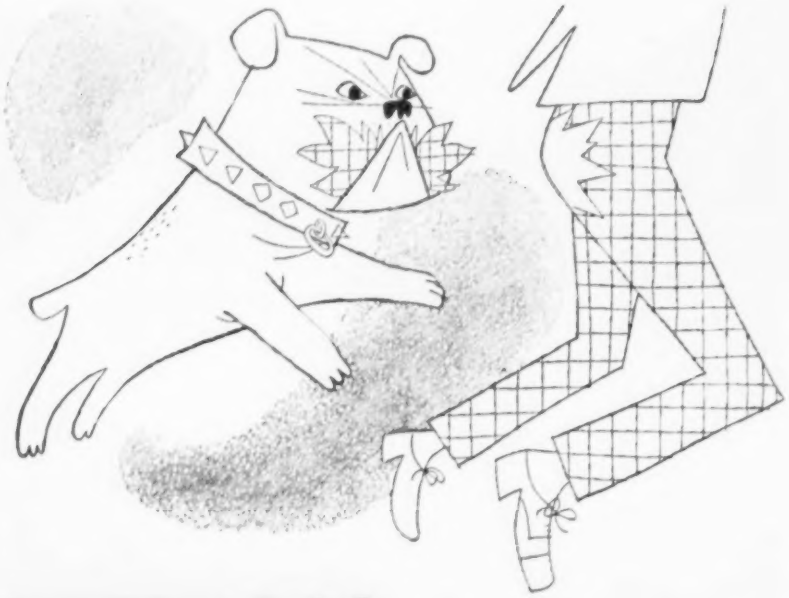

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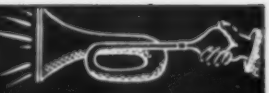

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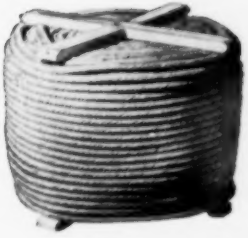

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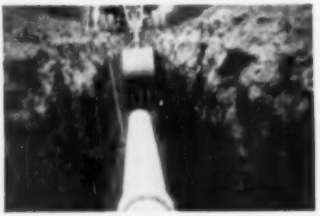

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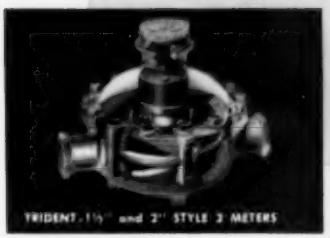

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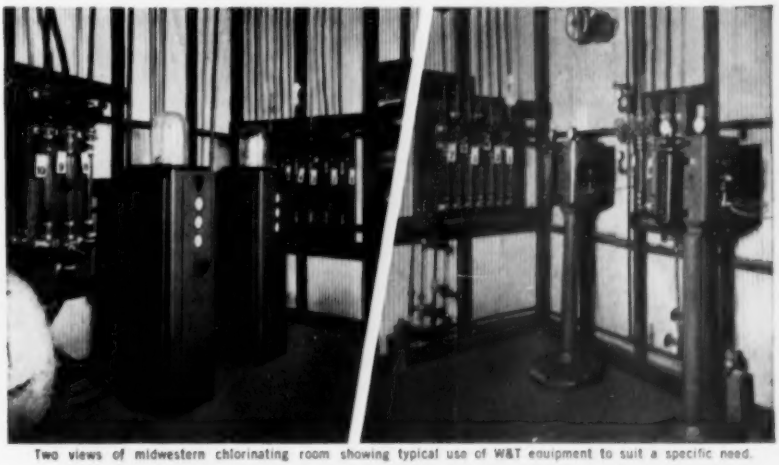

Two views of midwestern chlorinating room showing typical use of W&T equipment to suit a specific need.

To Every Part Its Proper Place . . .

How well chlorination equipment does its job depends not only on proper design but on the selection of the right parts and materials for every specific purpose.

The W&T equipment in the above installation is still giving good service after fifteen years. Every part in the equipment shown was designed specifically to meet a particular need. Mechanical diaphragms, first used by W&T in 1913, are here used for accurate control in the ammoniators. Puncture proof water diaphragms provide visibility and accessibility of control parts in the chlorinators. Both orifice and manometer type meters, and rotameters (furnished in W&T equipment as early as 1917), are employed here as best suiting the purpose for which each was intended.

Since 1913, W&T research has consistently sought out new designs, principles, and materials. Every new development is placed under rigid field tests to prove it can meet the exacting standards and practical limitations that dependable and economical chlorination demands.

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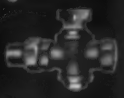
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5564
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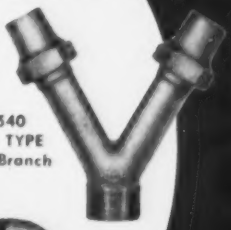
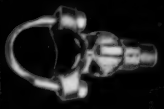
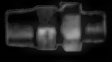
Three Branch


5540
"Y" TYPE
Two Branch

5596
"U" TYPE
Two Branch


DUO-STOP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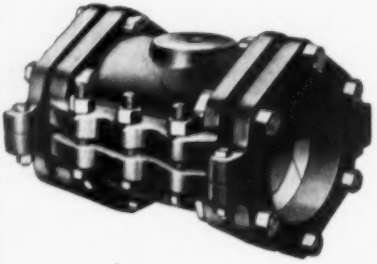

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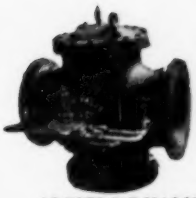

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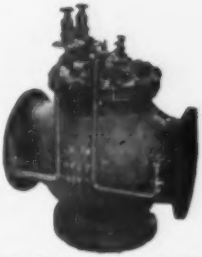

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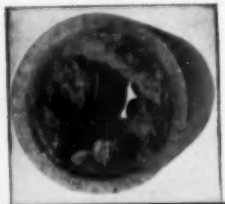

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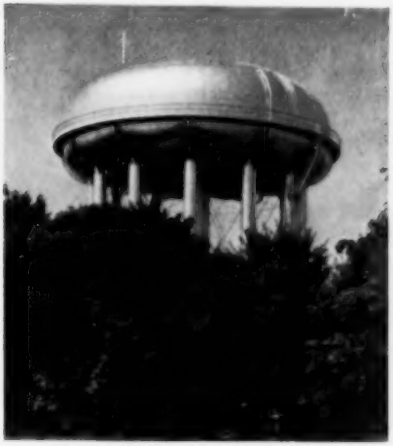

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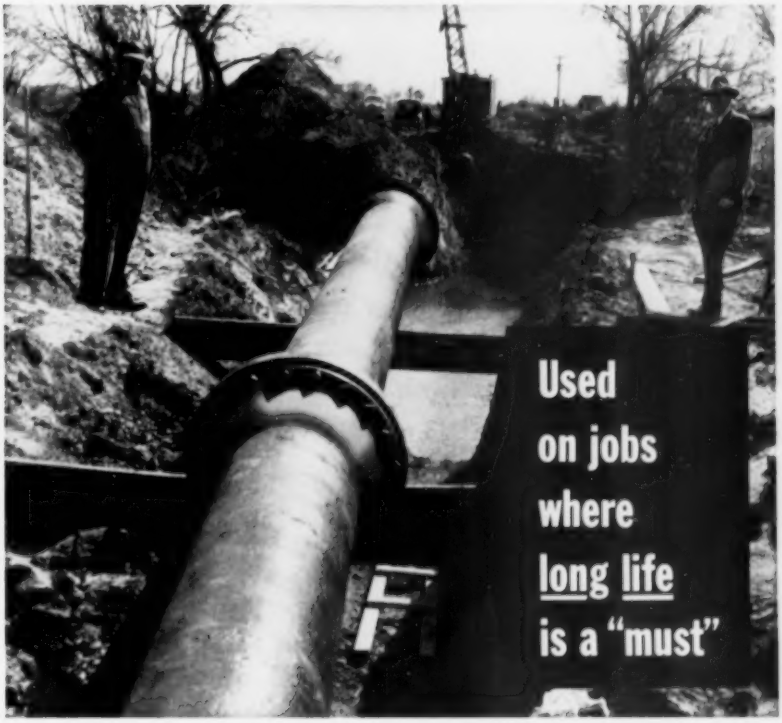

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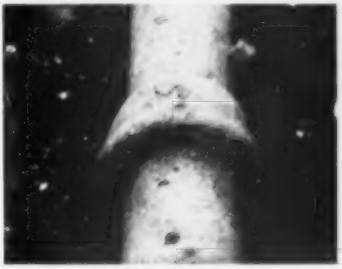

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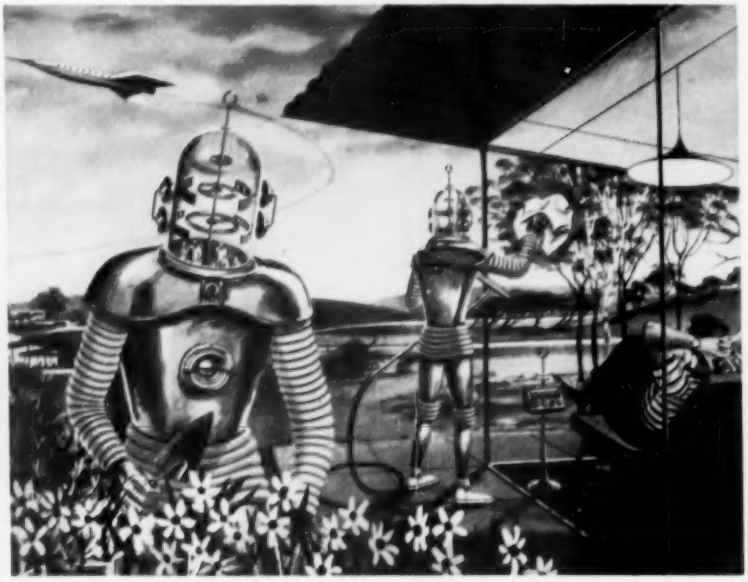

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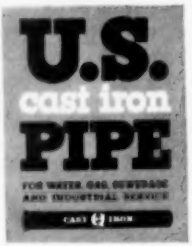

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